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(71) Applicant *(for all designated States except US)*: **CARL ZEISS SMT AG** [DE/DE]; Carl-Zeiss-Strasse 22, 73447 Oberkochen (DE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **DODOC, Aurelian** [RO/DE]; Hainbuchenweg 7, 73447 Oberkochen (DE). **ULRICH, Wilhelm** [DE/DE]; Lederackerring 44, 73434 Aalen (DE). **EPPLE, Alexander** [DE/DE]; Langertstrasse 38, 73431 Aalen (DE).

(74) Agent: **PATENTANWÄLTE RUFF, WILHELM, BEIER, DAUSTER UND PARTNER, ZUSAMMENSCHLUSS NR. 16**; Kronenstrasse 30, 70174 Stuttgart (DE).

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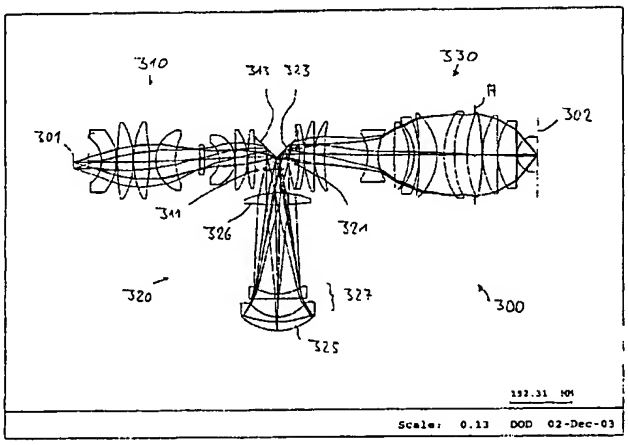
(54) Title: CATADIOPTRIC PROJECTION OBJECTIVE WITH INTERMEDIATE IMAGES



(57) Abstract: A catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective has a first objective part for imaging of an object field to form a first real intermediate image, a second objective part for production of a second real intermediate image using the radiation coming from the first objective part; and a third objective part for imaging of the second real intermediate image on the image plane. The second objective part is a catadioptric objective part with a concave mirror. A first folding mirror for deflection of the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflection of the radiation coming from the concave mirror in the direction of the image plane are provided. A field lens with a positive refractive power is arranged between the first intermediate image and/or the first folding mirror and the concave mirror, in an area close to the field of the first intermediate image.

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CATADIOPTRIC PROJECTION OBJECTIVE WITH INTERMEDIATE IMAGES

The following disclosure is based on US Provisional Application No. 60/571,533 filed on May 17, 2004 which is herewith incorporated into this application by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective.

Description of the Related Art

Projection objectives such as these are used in microlithography projection exposure systems for the production of semiconductor components and other finely structured components. They are used to project patterns of photomasks or reticles which are referred to in the following text in a general form as masks or reticles, onto an object which is coated with a light-sensitive layer, with very high resolution and on a reduced scale.

In this case, in order to produce ever finer structures, it is necessary on the one hand to enlarge the image-side numerical aperture (NA) of the projection objective, and on the other hand to use ever shorter wavelengths, preferably ultraviolet light at wavelengths of less than about 260 nm, for example 248 nm, 193 nm or 157 nm.

In the past, purely refractive projection objectives have been predominantly used for optical lithography. These are distinguished by a mechanically

relatively simple, centered design, which has only a single optical axis, that is not folded. Furthermore, it is possible to use object fields which are centered with respect to the optical axis, which minimize the light transmission level to be corrected, and simplify adjustment of the objective.

However, the form of the refractive design is primarily characterized by two elementary imaging errors: the chromatic correction and the correction for the Petzval sum (image field curvature).

Catadioptric designs, which have at least one catadioptric objective part and a hollow mirror or a concave mirror, are used to simplify the correction for the Petzval condition and to provide a capability for chromatic correction. In this case, the Petzval correction is achieved by the curvature of the concave mirror and negative lenses in its vicinity, while the chromatic correction is achieved by the refractive power of the negative lenses upstream of the concave mirror (for CHL) as well as the diaphragm position with respect to the concave mirror (CHV).

One disadvantage of catadioptric designs with beam splitting is, however, that it is necessary to work either with off-axis object fields, that is to say with an increased light conductance value (in systems using geometric beam splitting) or with physical beam splitter elements, which generally cause polarization problems. The term "light conductance value" as used here refers to the Lagrange optical invariant or Etendue, which is defined here as the product of the image field diameter and the image-side numerical aperture.

In the case of off-axis catadioptric systems, that is to say in the case of systems with geometric beam splitting, the requirements for the optical design can be formulated as follows: (1) reduce the light transmission level to the maximum extent, (2) design the geometry of the foldings (beam deflections) such that a mounting technology can be developed for this purpose, and (3) provide effective correction, in particular the capability to correct the

Petzval sum and the chromatic aberrations jointly in the catadioptric mirror group.

In order to keep the geometric light conductance value (Etendue) low, the folding of the design should in principle take place in the region of low NA, that is to say for example close to the object, or in the vicinity of a real intermediate image.

However, as the numeric aperture increases, the object-side numerical aperture also increases, and thus the distance between the first folding mirror and the reticle, so that the light transmission level rises. Furthermore, the diameter of the hollow mirror and the size of the folding mirror increase. This can lead to physical installation space problems.

These can be overcome by first of all imaging the reticle by means of a first relay system onto an intermediate image, and by carrying out the first folding in the area of the intermediate image. A catadioptric system such as this is disclosed in EP 1 191 378 A1. This has a refractive relay system, followed by a catadioptric objective part with a concave mirror. The light falls from the object plane onto a folding mirror (deflection mirror) which is located in the vicinity of the first intermediate image, from there to the concave mirror and from there onto a refractive object part, with a second real intermediate image being generated in the vicinity of a second deflection mirror, and the refractive object part images the second intermediate image on the image plane (wafer). Concatenated systems having, in that sequence, a refractive (R), a catadioptric (C), and a refractive (R) imaging subsystem will be denoted "R-C-R" type systems in the following.

Systems of type R-C-R with a similar folding geometry are disclosed in WO 2004/019128 A, WO 03/036361 A1 and US 2002/019946 A1. Patent application US 2004/0233405 A1 discloses R-C-R type projection objectives with different folding geometries including objectives where the first folding mirror is arranged optically downstream of the concave mirror to

deflect radiation coming from the concave mirror towards the image plane.

Other catadioptric systems with two real intermediate images are disclosed in JP 2002-372668 and in US Patent 5,636,066. WO 02/082159 A1 and WO 01/04682 disclose other catadioptric systems with more than one intermediate image.

SUMMARY OF THE INVENTION

It is one object of the invention to provide a catadioptric projection objective which allows very high resolutions to be achieved, with a compact design with optimized dimensions. It is another object to allow correction of the Petzval sum and of the chromatic aberrations with good manufacturing conditions.

As a solution to these and other objects this invention, according to one formulation, provides a catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having: a first objective part for imaging of an object field to form a first real intermediate image; a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and a third objective part for imaging the second real intermediate image on the image plane; wherein the second objective part is a catadioptric objective part with a concave mirror; a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided; and a field lens with a positive refractive power is arranged between the first intermediate image and the concave mirror, in a region close to the field of the first intermediate image.

According to another formulation, a field lens with a positive refractive power is arranged geometrically between the first folding mirror and the

concave mirror in a region close to the field of the first intermediate image. This position is optically between the first intermediate image and the concave mirror if the first intermediate image is created optically upstream, i.e. before the field lens in light propagation direction. The first intermediate image may also be positioned optically downstream, i.e. behind the field lens, or may partly extend into the field lens.

The enlargement of the numerical aperture which is required in order to achieve very high resolutions frequently leads in conventional systems to a major increase in the diameter of the optical components which are located in the area of preferred diaphragm positions. The invention counteracts this effect.

The expression "field lens" describes an individual lens or a lens group with at least two individual lenses. The expression takes account of the fact that the function of a lens can fundamentally also be carried out by two or more lenses (splitting of lenses). The refractive power of this field lens is arranged close to the field, that is to say in the optical vicinity of a field plane. This area close to the field for a field plane is distinguished in particular by the chief ray height of the imaging being large in comparison to the marginal ray height. In this case, the marginal ray height is the ray height of a marginal ray which leads from the innermost point of the object field, which is closest to the optical axis, to an edge of an aperture diaphragm, while the chief ray (principal ray) leads from the outermost field point of the object field parallel to, or at an acute angle to, the optical axis and intersects the optical axis in the area of the system diaphragm, that is to say at a diaphragm location which is suitable for the fitting of an aperture diaphragm. The ratio between the marginal ray height and the chief ray height is thus less than unity in the area close to the field.

The expression "intermediate image" describes the area between a paraxial intermediate image and an marginal ray intermediate image. Depending on the correction state of the intermediate image, this area may extend

over a certain axial range in which case, by way of example, the paraxial intermediate image may be located in the light path upstream or downstream of the marginal ray intermediate image, depending on the spherical aberration (undercorrection or overcorrection). The paraxial intermediate image and the marginal ray intermediate image may also essentially coincide. For the purposes of this application, an optical element A, for example a field lens, is located "between" an intermediate image and another optical element B when at least a portion of the optical element A is located between the (generally axially extended) intermediate image and the optical element B. The intermediate image may thus also partially extend beyond an optical surface which, for example, may be advantageous for correction purposes. The intermediate image is frequently located completely outside optical elements. Since the radiation energy density in the intermediate image area is particularly high, this may be advantageous, for example, with respect to the radiation load on the optical elements.

Positive refractive power in the divergent beam path between an upstream intermediate image and the concave mirror contributes to the capability for the downstream lenses in the beam path and the concave mirror to have small diameters. This applies in particular to the at least one negative lens which is provided in preferred embodiments in the immediate vicinity upstream of the concave mirror and which, in conjunction with the concave mirror, makes a major contribution to the correction of the chromatic longitudinal aberration CHL. If the chromatic longitudinal aberration is corrected in some other way, there is no need for this negative lens.

The insertion of positive refractive power between a field plane upstream of the concave mirror and the concave mirror leads in its own right to a contribution to the image field curvature which is proportional to the strength of the positive refractive power. In order to at least partially compensate for this effect, the concave mirror should have greater curvature than in the absence of the positive refractive power. In order, on the other hand, to keep the aberrations which are introduced by the reflection on the concave mirror as small as possible, it is advantageous for the radiation

mirror as small as possible, it is advantageous for the radiation which strikes the concave mirror to strike it essentially at right angles. When positive refractive power is inserted downstream from the intermediate image, this leads to an increase in the negative refractive power directly upstream of the concave mirror, in order to ensure largely perpendicular radiation incidence by virtue of the scattering effect. The increase in the negative refractive power upstream of the concave mirror can at least partially compensate for the reduction in the CHL correction by reducing the size of the lens diameter in this area, so that good CHL correlation is ensured even with a relatively small mirror diameter.

In preferred embodiments, the first intermediate image is located in the vicinity of a folding mirror, which makes it possible to keep the Etendue of the system small. The field lens can generally be fitted very close to the intermediate image without being adversely affected by the folding mirror, thus allowing effective correction of imaging errors. In particular, the objective parts can be suitably designed in order to ensure that at least the intermediate image which is close to the field lens is subject to severe aberration. This allows particularly effective correction of imaging errors. The effectiveness of the correction can be assisted by designing at least that lens surface of the field lens which faces the intermediate image as an aspherical surface.

In one embodiment, the field lens is arranged geometrically between the concave mirror and at least one folding mirror in a region through which the beam passes twice, in such a manner that a first lens area of the field lens is arranged in the beam path between the object plane and the concave mirror, and a second lens area of the field lens is arranged in the beam path between the concave mirror and the image plane.

The field lens can be arranged such that it is arranged not only in the optical vicinity of an intermediate image plane which is located in the beam path upstream of the concave mirror, but also in the optical vicinity of an

intermediate image plane which is located in the beam path downstream from the concave mirror. This results in an arrangement close to the field with respect to two successive field planes, so that a powerful correction effect can be achieved at two points in the beam path.

At least one multiple area lens can be arranged in a region of the projection objective through which the beam passes twice and has a first lens area, through which the beam passes in a first direction, and a second lens area, through which the beam passes in a second direction, with the first lens area and the second lens area not overlapping one another, at least on one side of the lens. This multiple area lens may be used as a field lens. If the footprints of the beam paths do not overlap on at least one of the two lens faces, a multiple area lens such as this allows two lenses which act independently of one another to be geometrically moved to a common point. It is also possible to physically manufacture two lenses which act independently of one another as one lens, specifically as an integral multiple area lens, from one lens blank. A multiple area lens such as this can be clearly distinguished from a conventional lens through which the beam passes twice since, in the case of a multiple area lens of this type its optical effect on the beams which pass through it independently of one another can be influenced by suitable independent shaping of the refractive surfaces of the lens areas independently of one another. Alternatively, a lens arrangement with one or two half-lenses or lens elements can also be arranged at the location of an integral multiple area lens in order to influence the beams as they pass one another, independently of one another.

Projection objectives with geometric beam splitting, an intermediate image and a multiple area lens have been disclosed, for example, in WO 03/052462 A1 from the same applicant. The disclosure in this patent application is included by reference in the content of this description.

The projection objective preferably has an image-side numerical aperture of NA > 0.85, and an image-side working distance of A ≤ 10 mm. Projection

objectives such as these may be used, if required, or immersion lithography with NA > 1. The image-side working distance or the working distance in the image area is the (shortest) axial distance between the exit surface of the objective and the image plane. This working distance in the image area, which is filled with a gas during operation in dry systems, is filled with an immersion medium during operation in immersion systems, with the immersion medium having a refractive index which is relatively high in comparison to that of gas.

It is generally advantageous for the image-side working distance not to fall below a minimum value. In this case, it should be noted that scratches, dirt and inhomogeneities on or in the last optical element can lead to a disturbance of the image if the working distance is too short. A finite working distance of, for example, 1 mm or more can in contrast lead to relatively large sub-apertures (footprints of one specific field point) with the high image-side numerical apertures, so that an averaging effect can occur and any image disturbance is reduced or suppressed.

Particular criteria must be taken into account for the definition of the working distance in the image area in immersion systems. On the one hand, a long working distance results not only in greater radiation losses owing to the normally lower transmission of immersion liquids (in comparison to gases) but also to a greater amount of aberration of the surfaces which are located in the vicinity of the image plane, specifically for spherical aberration. On the other hand, the image-side working distance should be sufficiently large to allow laminar flow of an immersion fluid. It may also be necessary to provide space for measurement purposes and sensors. In preferred embodiments, the image-side working distance is between about 1 mm and about 8 mm, in particular between about 1.5 mm and about 5 mm. When using an immersion fluid between the exit surface and the image plane, preferred embodiments have an image-side numerical aperture of $NA \geq 0.98$, with the image-side numerical aperture preferably being at least $NA = 1.0$, or at least $NA = 1.1$. The projection objective is preferably

matched to an immersion medium which has a refractive index of $n_l > 1.3$ at an operating wavelength.

Very pure water for which $n_l \approx 1.43$ is suitable as an immersion medium for an operating wavelength of 193 nm. The article "Immersion Lithography at 157 nm by M. Switkes and M. Rothschild, J. Vac.Sci. Technol. B 19(6), Nov/Dec. 2001, pages 1 et seq proposes immersion liquids based on perfluoropolyethers (PFPE) which are sufficiently transparent for an operating wavelength of 157 nm and are compatible with a number of photoresist materials that are currently used in microlithography. One tested immersion liquid has a refractive index of $n_l=1.37$ at 157 nm.

The optical design also allows use for non-contacting near-field projection lithography. In this case, sufficient light energy can be injected into the substrate to be exposed via a gap which is filled with gas, provided that a sufficiently short image-side working distance is maintained, averaged over time. This should be less than four times the operating wavelength that is used, in particular less than the operating wavelength. It is particularly advantageous for the working distance to be less than half the operating wavelength, for example less than one third, one quarter or one fifth of the operating wavelength. These short working distances allow imaging in the optical near field in which evanescent fields, which exist in the immediate vicinity of the last optical surface of the imaging system, are used for imaging.

The invention thus also covers a non-contacting projection exposure method in which evanescent fields of the exposure light which are located in the immediate vicinity of the exit surface can be used for the lithographic process. In this case, if the working distances are sufficiently short (finite), a light component which can be used for lithography can be emitted from the exit surface of the objective, and can be injected into an entry surface, which is immediately adjacent at a distance, despite geometrical total internal reflection conditions on the last optical surface of the projection objec-

tive.

Embodiments for non-contacting near-field projection lithography preferably use typical working distances in the region of the operating wavelength or less, for example between about 3 nm and about 200 nm, in particular between about 5 nm and about 100 nm. The working distance should be matched to the other characteristics of the projection system (characteristics of the projection objective close to the exit surface, characteristics of the substrate close to the entry surface) so as to achieve an input efficiency of at least 10%, averaged over time.

A method for production of semiconductor components and the like is thus possible within the scope of the invention, in which a finite working distance is set between an exit surface for exposure light which is associated with the projection objective and an entry surface for exposure light which is associated with the substrate, with the working distance within an exposure time interval being set, at least at times, to a value which is less than a maximum extent of an optical near field of the light emerging from the exit surface.

Use as a dry objective is also possible, if required, with minor modifications. Dry objectives are designed such that a gap which is filled with gas is produced during operation between the exit surface of the projection objective and the entry surface of an object to be exposed, for example a wafer, with this gap width typically being considerably greater than the operating wavelength. The achievable numerical apertures with systems such as these are restricted to values $NA < 1$, since total internal reflection conditions occur on the exit surface on approaching the value $NA = 1$, preventing any exposure light from being emitted from the exit surface. In preferred embodiments of dry systems, the image-side numerical aperture is $NA \geq 0.85$ or $NA \geq 0.9$.

The third objective part immediately upstream of the image plane is pref-

erably designed to be purely refractive, and can be optimized in order to produce high image-side numerical apertures (NA). It preferably has a first lens group, which follows the second intermediate image, and has a positive refractive power, a second lens group, which immediately follows the first lens group and has a negative refractive power, a third lens group which immediately follows the second lens group and has a positive refractive power, a fourth lens group which immediately follows the third lens group and has a positive refractive power, and a pupil surface which is arranged in a transitional region from the third lens group to the fourth lens group and in whose vicinity a system diaphragm can be arranged. The third lens group preferably has an entry surface which is located in the vicinity of a point of inflection of a marginal ray height between the second lens group and the third lens group, with no negative lens with any substantial refractive power being arranged between this entry surface and the system diaphragm. There are preferably only positive lenses between this entry surface and the image plane. This allows a material-saving design, with moderate lens diameters.

The last optical element in the projection objective immediately upstream of the image plane is preferably a plano-convex lens with a high spherical or aspherically curved entry surface and an exit surface which is essentially planar. This may be in the form of a plano-convex lens which is virtually hemispherical or is not hemispherical. The last optical element, in particular the plano-convex lens, may also be composed of calcium fluoride in order to avoid problems resulting from radiation-induced density changes (in particular compaction).

The first objective part may be used as a relay system in order to produce a first intermediate image, with a predetermined correction state at a suitable position, from the radiation coming from the object plane. The first objective part is generally purely refractive. In some embodiments, at least one folding mirror is provided in this first objective part, which images the object plane to form a first intermediate image, such that the optical axis is

folded at least once, and preferably no more than once, within the objective part which is closest to the object.

In some embodiments, the first objective path is a catadioptric objective part with a concave mirror and an associated folding mirror, which may be used as the first folding mirror for the overall projection objective.

The provision of at least two catadioptric subsystems has major advantages. In order to identify significant disadvantages of systems with only one catadioptric subsystem, it is necessary to consider how the Petzval sum and the chromatic aberrations are corrected in a catadioptric part. The contribution of a lens to the chromatic longitudinal aberration CHL is proportional to the square of the marginal ray height h, to the refractive power φ of the lens, and to the dispersion ν of the material. On the other hand, the contribution of a surface to the Petzval sum depends only on the surface curvature and of the sudden change in the refractive index (which is – 2 in the case of a mirror in air).

In order to allow the contribution of the catadioptric group to the chromatic correction to become large, large marginal ray heights (that is to say large diameters) are thus required, and large curvatures are required in order to allow the contribution to the Petzval correction to become large (that is to say small radii, which are best achieved with small diameters). These two requirements are contradictory.

The contradictory requirements based on Petzval correction (that is to say correction of the image field curvature) and chromatic correction can be solved by introduction of (at least) one further catadioptric part into the system. Since the first catadioptric objective part can be designed such that both the image field curvature and the chromatic longitudinal aberration can be largely or completely corrected, the first intermediate image may have a defined correction state with respect to these aberrations, so that the subsequent objective parts may have an advantageous design.

In one embodiment, the first objective part is a catadioptric objective part with a physical beam splitter, which has a polarization-selective beam splitter surface which is used as a folding mirror and at the same time separates that radiation which leads to the concave mirror of the first objective part from that radiation which is reflected by this concave mirror.

In some embodiments, a concave mirror is provided which is designed as an active mirror, so that the shape of the concave mirror surface can be varied by a suitable drive. This can be used to compensate for various imaging errors.

Some embodiments of projection objectives according to the invention have a crossed beam path at at least one point. For this purpose, they are designed such that a first beam section which runs from the object plane to a concave mirror and a second beam section which runs from the concave mirror to the image plane can be produced, and one folding mirror is arranged with respect to the concave mirror in such a manner that one of the beam sections is folded on the folding mirror, and the other beam section passes through the folding mirror without any vignetting, and the first beam section and the second beam section cross over in a crossing region.

The crossed beam path in the region of a catadioptric objective part, allows projection objectives with a compact and mechanically robust arrangement of the optical components. In this case, a beam path without any vignetting can be achieved, so that no folding mirror intersects a beam which is either reflected on the folding mirror or is passed by the folding mirror without reflection. In this way, only the system diaphragm limits the angular distribution of the rays which contribute to imaging, in an axially symmetrical manner. At the same time, even with the largest numerical apertures, which are associated with large maximum beam diameters and, possibly, highly convergent or divergent beams in the region of the field planes, it is possible to achieve a moderate size for the overall field to be corrected. In this case,

the expression "overall field" describes the field area which is enclosed by a minimum circle around the generally rectangular field. The size of the overall field to be corrected increases with the field size and the lateral offset of an axially asymmetric field with respect to the optical axis, and should be minimized in order to simplify the correction process.

Catadioptric projection objectives with a crossed beam path are disclosed, for example, in the US provisional application with the serial number 60/511,673, which was filed on October 17, 2003, or the US patent application with the serial number 10/734,623, which was filed on December 27, 2003, or the US provisional application with the serial number 60/530,622, which was filed on December 19, 2003, by the same applicant. The disclosure content of these patent applications is included by reference in the content of this description.

In preferred embodiments, an off-axis effective object field arranged in the object surface of the projection objective is imaged onto an off-axis effective image field arranged in the image surface of the projection objective. Here, the term "effective object field" relates to the object field which can be effectively imaged by the projection objective without vignetting at a given numerical aperture. The amount of a lateral offset between the effective object field and the first part of the optical axis defined by the first objective part may be characterized by a finite object center height h. Likewise, on the image side of the projection objective, the effective image field is laterally offset with respect to the image side part of the optical axis by a finite image center hight h' related to the object center hight h by the magnification ratio β of the projection objective according to $h' = |\beta \cdot h|$. In some conventional projection objectives having a refractive first objective part, a catadioptric second objective part, and a refractive third objective part (also denoted type R-C-R) efforts have been made to align the parts of the optical axis defined by the object side refractive objective part and the image side refractive objective part

such that no lateral axis offset exists between these parts of the optical axis. However, under these conditions, a finite value of an object-image-shift (OIS) defined between an object field center and an image field center results. Where the object surface and the image surface of the projection objective are parallel to each other, the object-image-shift may be defined as a lateral offset between an object field center axis running parallel to the object side optical axis through the center of the effective object field and an image field center axis running parallel to the image side part of the optical axis through the center of the effective image field. It has been found that small values of object-image-shift may be desireable e.g. if the projection objective is to be incorporated into a projection exposure system designed for scanning operations. Also, measuring techniques used for the qualification of the projection objective may be simplyfied with respect to conventional measuring techniques if small amounts of object-image-shift are obtained. Therefore, in preferred embodiments, the following condition holds:

$$0 \leq OIS \leq |h \bullet (1+|\beta|)|.$$

In embodiments obeying this condition, the object-image-shift OIS is smaller than the object-image-shift of designs where the object side part of the optical axis and the image side part of the optical axis are coaxial. In preferred embodiments, no object-image-shift is present such that the condition OIS = 0 is fulfilled.

These conditions may be useful in embodiments of the invention having a field lens with positive refractive power arranged between the first intermediate image and the concave mirror in the optical vicinity of the first intermediate image. However, small values for OIS may also be useful for conventional designs having no field lens of this type, such as shown e.g. in WO 2004/019128 A.

Another aspect of the invention enables designing projection objectives having potential for very high image side numerical apertures NA > 1,2 or NA > 1,3 while at the sime time the overall track length (axial distance between object surface and image surface) can be limited to values allowing incorporation of the projection objective in conventional projection exposure systems and, at the same time, allowing to limit the maximum size (diameter) of lenses in the refractive objective parts upstream and/or downstream of a folding mirror. To this end, in preferred embodiments, a refractive power and a position of the field lens is set such that for a first chief ray direction cosine CRA_1 at the first intermediate image the following condition holds:

$$|CRA1| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$

where β_1 denotes the magnification of the first objective part , Y_{OB} is the object height of the outermost field point for which the chief ray is considered and L_{HOA} is the geometrical distance from the first intermediate image to the concave mirror (length of the horizontal axis). With other words, it may be desireable that the chief ray is telecentric or almost telecentric at a an intermediate image. A chief ray obeying the condition given above will be denoted as an "essentially telecentric chief ray" in the following. Providing an essentially telecentric chief ray at a folding mirror close to such interrmediate image allows to limit the size of lenses immediately upstream and/or downstream of the folding mirror. In addition, it has been found that installation space within the third objective part responsible for providing high image side numerical apertures is obtained.

Further, in some embodiments it has been found beneficial for obtaining very high image side numerical apertures if a first axial length AL1 of the first objective part is smaller than a third axial length AL3 of the third objective part, wherein the axial length AL1 is

measured between the object plane and an intersection of the optical axis with the first folding mirror and the axial length AL3 is measured between the intersection of the optical axis with the second folding mirror and the image plane. In preferred embodiments, the condition AL1/AL3 < 0,9, more preferably AL1/AL3 < 0,8 holds

Systems according to the invention can preferably be used in the deep UV band, for example at 248 nm, 193 nm or 157 nm, or less.

These features and further features are evident not only from the claims but also from the description and the drawings, in which case the individual features can be implemented in their own right or together in the form of subcombinations of embodiments of the invention, and in other fields, and can represent advantageous embodiments, as well as embodiments which are worthy of protection in their own right.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic illustration of a projection exposure system for immersion lithography with one embodiment of a catadioptric projection objective according to the invention;

Fig. 2 shows a schematic illustration of the design of preferred embodiments of projection objectives according to the invention, with a refractive first objective part, a catadioptric second objective part, and a refractive third objective part;

Fig. 3 shows a lens section through a first embodiment of a projection objective according to the invention;

Fig. 4 shows a lens section through a second embodiment of a projection objective according to the invention;

Fig. 5 shows a schematic illustration of the design of one embodiment of a projection objective according to the invention, with a different folding geometry and a crossed beam path;

Fig. 6 shows a schematic illustration of one embodiment of a projection objective according to the invention, with a catadioptric first objective part, a catadioptric second objective part and a refractive third objective part;

Fig. 7 shows a lens section for one embodiment of a catadioptric first objective part with a physical beam splitter, which can be used for the design shown in Fig. 6;

Fig. 8 shows various mirror arrangements for folding mirrors for projection objectives according to the invention;

Fig. 9 shows a lens section for an embodiment having coaxial first and third objective parts;

Fig. 10 shows a lens section for another embodiment having coaxial first and third objective parts;

Fig. 11 shows a lens section through an embodiment having laterally offset first and third objective parts such that there is no object-image-shift (OIS), where Fig. 11' illustrates the conditions therefore;

Fig. 12 shows a lens section through a reference system having no field lens;

Fig. 13 shows a lens section through an embodiment having an essentially telecentric chief ray at the folding mirrors;

Fig. 14 shows scematic drawings illustrating the trajectories of the chief ray in a conventional system (a) and according to embodiments having an essentially telecentric chief ray at the folding mirrors (b);

Fig. 15 shows a lens section through another emobidment having essentially telecentric chief rays at the folding mirrors and a field lens geometrically close to the folding mirrors, where the field lens is optically situated both in the first objective part and in the third objective part;

Fig. 16 shows a lens section of an embodiment having a field lens further apart from the folding mirrors optically within the catadioptric, second objective part and having NA=1,30; and

Fig. 17 shows a variant of the projection objective of Fig. 16 having NA=1,35.

In the following description of preferred embodiments, the expression "optical axis" means a straight line or a sequence of straight line sections through the centers of curvature of the optical components. The optical axis is folded on folding mirrors (deflection mirrors) or on other reflective surfaces. Directions and distances are described as being on the "image side" when they are directed in the direction of the image plane or of the substrate which is located there and is to be exposed, and as on the "object side" when they are directed toward the object plane or toward a reticle located there, with respect to the optical axis. The object in the examples is a mask (reticle) with the pattern of an integrated circuit, although it may also be a different pattern, for example a grating. The image in the examples is projected onto a wafer which is provided with a photoresist layer and is used as a substrate. Other substrates, for example elements for liquid crystal displays or substrates for optical gratings, are also possible.

Fig. 1 shows, schematically, a microlithographic projection exposure system in the form of a wafer stepper 1, which is intended for production of large-scale integrated semiconductor components by means of immersion lithography. The projection exposure system 1 has an excimer laser 2 as the light source, with an operating wavelength of 193 nm, although other operating wavelengths, for example 157 nm or 248 nm, are also possible. A downstream illumination system 3 produces a large, sharply constricted, highly homogeneously illuminated illumination field, which is matched to the telecentric requirements of the downstream projection objective 5 on its exit plane 4. The illumination system 3 has devices for selection of the illumination mode and, in the example, can be switched between conventional illumination with a variable coherence degree, annular field illumination and dipole or quadrupole illumination.

A device 40 (reticle stage) for holding and manipulating a mask 6 is arranged behind the illumination system in such a way that it is located on the object plane 4 of the projection objective 5, and can be moved in a departure direction 7 (y direction) on this plane, for scanning purposes.

The plane 4, which is also referred to as the mask plane, is followed by the catadioptric reduction objective 5, which images an image of the mask on a reduced scale of 4:1 on a wafer 10 which is covered with a photoresist layer. Other reduction scales, for example 5:1, 10:1 or 100:1 or more, are likewise possible. The wafer 10 which is used as a light-sensitive substrate, is arranged such that the planar substrate surface 11 together with the photoresist layer essentially coincides with the image plane 12 of the projection objective 5. The wafer is held by a device 50 (wafer stage) which comprises a scanner drive in order to move the wafer synchronously with the mask 6 and parallel to it. The device 50 also has manipulators, in order to move the wafer both in the z direction parallel to the optical axis 13 of the projection objective and in the x and y directions at right angles to this axis. A tilting device is integrated, and has at least one tilting axis which runs at right angles to the optical axis 13.

The device 50, which is provided for holding the wafer 10, is designed for use for immersion lithography. It has a holding device 15, which can be moved by a scanner drive and whose base has a flat depression or recess for holding the wafer 10. A flat liquid-tight holder, which is open at the top, for a liquid immersion medium 20 is formed by a circumferential rim 16, and the immersion medium 20 can be introduced into the holder, and can be carried away from it, by devices that are not shown. The height of the rim is designed such that the filled immersion medium completely covers the surface 11 of the wafer 10, and the exit-side end area of the projection objective 5 can be immersed in the immersion liquid between the objective exit and the wafer surface while the working distance is set correctly. The entire system is controlled by a central computer unit 60.

Fig. 2 schematically illustrates one preferred embodiment of projection objectives according to the invention. The projection objective 200 is used to image a pattern (which is arranged on its object plane 201) of a mask on a reduced scale on its image plane 202, which is aligned parallel to the object plane, on a reduced scale. It has a first, refractive objective part 210, which images the object field to form a first, real intermediate image 211, a second, catadioptric objective part 220, which images the first intermediate image to form a second real intermediate image 221, and a third, refractive objective part 230, which images the second intermediate image on a reduced scale on the image plane 202. The catadioptric objective part 220 has a concave mirror 225. A first folding mirror 213 is arranged in the vicinity of the first intermediate image, at an angle of 45° to the optical axis 204, such that it reflects the radiation coming from the object plane in the direction of the concave mirror 225. A second folding mirror 223, whose planar mirror surface is aligned at right angles to the planar mirror surface of the first folding mirror, reflects the radiation coming from the concave mirror 225 in the direction of the image plane 202.

The folding mirrors 213, 223 are each located in the optical vicinity of the

intermediate images, so that the light conductance value can be kept low. The intermediate images, that is the entire region between the paraxial intermediate image and the marginal ray intermediate image, are preferably not located on the mirror surfaces, thus resulting in a finite minimum distance between the intermediate image and the mirror surface, so that any faults in the mirror surface, for example scratches or impurities, are not imaged sharply on the image plane. The minimum distance should be set such that sub-apertures of the radiation, that is to say footprints of beams which originate from a specific field point or converge on it do not have a diameter of less than 5 mm, or 10 mm, on the mirror surface. Embodiments exist in which both the first intermediate image 211, that is to say the second intermediate image 221 as well, are located in the geometric space between the folding mirrors and the concave mirror 225 (solid arrows). This side arm is also referred to as the horizontal arm (HOA). In other embodiments, the first intermediate image 211' may be located in the beam path upstream of the first folding mirror 213, and the second intermediate image 221' may be located in the beam path downstream from the second folding mirror (arrows represented by dashed lines).

The folding angles in this exemplary embodiment are exactly 90°. This is advantageous for the performance of the mirror layers of the folding mirrors. Deflections by more or less than 90° are also possible, thus resulting in an obliquely positioned horizontal arm.

All of the objective parts 210, 220, 230 have a positive refractive power. In the schematic illustration, lenses or lens groups with a positive refractive power are represented by double-headed arrows with points pointing outwards, while lenses or lens groups with a negative refractive power are, in contrast, represented by double-headed arrows with heads pointing inwards.

The first objective part 210 comprises two lens groups 215, 216 with a positive refractive power, between which a possible diaphragm position

exists where the chief ray 203, which is shown by a solid line, intersects the optical axis 204, which is shown by a dashed-dotted line. The optical axis is folded through 90° at the first folding mirror 213. The first intermediate image 211 is produced in the light path immediately downstream from the first folding mirror 213.

The first intermediate image 211 acts as an object for the subsequent catadioptric objective part 220. This has a positive lens group 226 close to the field, a negative lens group 227 close to the diaphragm, and the concave mirror 225 which is arranged immediately downstream from this and images the first intermediate image to form the second intermediate image 221. The lens group 226, which has a positive effect overall, is used as a "field lens" and is formed by a single positive lens, whose effect can also be produced, however, by two or more individual lenses with a positive refractive power overall. The negative lens group 227 comprises one or more lenses with a negative effect.

The second intermediate image 221, which is located optically immediately in front of the second folding mirror 223, is imaged by the third refractive objective part 230 on the image plane 202. The refractive objective part 230 has a first positive lens group 235, a second negative lens group 236, a third positive lens group 237 and a fourth positive lens group 238. There is a possible diaphragm position between the positive lens groups 237, 238, where the chief ray intercepts the optical axis.

Fig. 3 shows a lens section through a projection objective 300 which is essentially formed using the principles explained with reference to Fig. 2. Identical or corresponding elements or element groups are annotated with the same reference symbols as in Fig. 2, increased by 100.

One special feature of the system is that a biconvex positive lens 326, through which the beam passes in two opposite directions, is provided geometrically between the folding mirrors 313, 323 and the concave mirror

325 in a region of the projection objective through which the beam passes twice, with the beam passing through it both in the light path between the first intermediate image 311 and the concave mirror 325 and in the light path between the concave mirror and the second intermediate image 321, or the image plane 302, in mutually offset lens areas. The positive lens 326 is arranged closer to the folding mirrors 313, 323 than to the concave mirror 325, in particular in the first third of the axial distance between the folding mirrors and the concave mirror. In the region of the positive lens 326, the marginal ray height is small in comparison to the chief ray height, with the ratio of the marginal ray height to the chief ray height being approximately 0.3. The positive lens 326 is thus arranged close to the field both with respect to the first intermediate image 311 and with respect to the second intermediate image 321, and thus acts as a field lens for both intermediate images. The positive refractive power in the light path between the first intermediate image 311 and the concave mirror 325 ensures, inter alia, that the diameters of the subsequent lenses 327 and of the concave mirror 325 can be kept small. The positive refractive power in the light path from the concave mirror to the second intermediate image 321 and to the image plane results in a reduction in the incidence angle bandwidth of the radiation which also arrives at the second folding mirror 323 and can thus be coated with advantageous reflection layers, as well as for limiting the lens diameters in the refractive objective part 330 which is closest to the image field and is essentially responsible for production of the high image-side numerical aperture (NA = 1.20) of the immersion projection objective.

The positive lens can be moved very close to the two intermediate images when required, without being impeded by the folding mirrors, so that a strong correction effect is possible. The positive refractive power which is arranged close to the field allows the horizontal arm to be longer. Because of the large aperture in the first intermediate image 311, the length of the horizontal arm would normally be shortened, so that the diameter of the concave mirror 325 and of the negative meniscus lenses in the negative group 327 which are arranged immediately upstream of it is linked to the

color correction and should therefore not be indefinitely large. The inclusion of a positive lens group 326 close to the field also increases the refractive power of the negative lenses 327, owing to the compensation for the Petzval curvature (in comparison to the concave mirror), and thus increases the correction of the color longitudinal error for relatively small diameters in the area of the concave mirror. The catadioptric objective part can thus be designed to be compact and with relatively small lens dimensions, with adequate color correction.

The field lens 326 which is arranged in the immediate vicinity of two intermediate images 311, 321 also has major advantages with respect to optical correction, as will be explained in more detail in the following text. In principle, it is advantageous for the correction of imaging errors to have optical surfaces in the vicinity of intermediate images which are subject to major aberrations. The reason for this is as follows: at a long distance from the intermediate image, for example in the vicinity of the system diaphragm or its conjugate planes, all of the opening rays in a light beam have a finite and monotonally rising height with the pupil coordinate, that is to say an optical surface acts on all the opening rays. Opening beams which are located further outwards at the pupil edge also have an increasingly greater height on this surface (or more correctly: an increasing distance from the chief ray).

However, this is no longer the case in the vicinity of an intermediate image which is subject to severe aberrations. If one is, in fact, located within the caustic of the intermediate image, then it is possible for the surface to be located approximately in or close to the marginal ray image, that is to say effectively it does not act on the marginal rays, but has a considerable optical effect on the zone rays. It is thus possible, for example, to correct a zone error in the optical aberrations. This principle may be used, for example, in order to deliberately influence the spherical zone error.

The convex lens surface of the positive lens 326 which faces the interme-

diate images 311, 321 and is arranged in their immediate proximity is aspherically curved. In conjunction with the arrangement close to the field, this allows a very major corrective effect to be achieved.

At least the two to three lenses closest to the image can be manufactured from calcium fluoride, in order to avoid compaction problems. In order to compensate for intrinsic birefringence, the crystallographic major axes of the lenses can be rotated with respect to one another. The concave mirror 325 may also be in the form of an active mirror, in which the shape of the mirror surface can be varied by means of suitable manipulators. This can be used to compensate for various imaging errors. The beam path in the vicinity of at least one of the intermediate images is virtually telecentric.

Table 1 shows the specification of the design in tabular form. In this case, column 1 shows the number of the surface which is refractive, reflective or is distinguished in some other way, column 2 shows the radius r of the surface (in mm), column 3 shows the distance d between the surface and the subsequent surface (in mm), column 4 shows the material of a component, and column 5 shows the optically useable free diameters of the optical components (in mm). Reflective surfaces are annotated by "R" in column 1. Table 2 shows the corresponding aspherical data, with the arrow heights of the aspherical surfaces being calculated using the following rule:

$$p(h)=[((1/r)h^2/(1+SQRT(1-(1+K)(1/r)^2h^2))]+C1*h^4+C2*h^6+...$$

In this case, the reciprocal (1/r) of the radius indicates the surface curvature at the surface apex, and h indicates the distance between the surface point and the optical axis. The arrow height is thus p(h), that is to say the distance between the surface point and the surface apex in the z direction, that is to say in the direction of the optical axis. The constants K, C1, C2, etc. are shown in Table 2.

The immersion objective 300 is designed for an operating wavelength of

about 157 nm, at which the calcium fluoride which is used for all of the lenses has a refractive index of n = 1.5593. This is matched to a perfluoropolyether (Fomblin®) which is used in vacuum technology, as an immersion medium for which n_I = 1.37 at 157 nm, and has an image-side working distance of about 1.5 mm. The image-side numerical aperture NA is 1.2, and the imaging scale reduction factor is 4:1. The system is designed for an image field whose size is 26 × 5.0 mm^2, and it is double telecentric.

Fig. 4 shows a lens section through a projection objective 400 which represents a variant of the embodiment shown in Fig. 3 and is likewise formed using the principles explained with reference to Fig. 2. Identical or corresponding elements or element groups are annotated with the same reference symbols as in Fig. 3, increased by 100. The specifications for this exemplary embodiment are shown in Tables 3 and 4.

In this embodiment as well, a biconvex positive lens 426 which is used as a field lens is arranged in the horizontal arm in the immediate optical vicinity of the intermediate images 411, 421 which are arranged between the folding mirrors 413, 423 and the concave mirror 425, thus resulting in the horizontal arm having small dimensions and on the other hand in a major corrective effect to the intermediate images.

A further special feature of this embodiment is the design of the third, refractive objective part 430, which has a particularly compact configuration, with small dimensions and a small maximum diameter. The basic design with an initial positive group 435, followed by the negative group 436 and two subsequent positive groups 437, 438 with an aperture diaphragm (aperture stop) A in between corresponds to the design shown in Fig. 3. The entry surface E of the third lens group 437 is located behind the biconcave negative lens 436, which is the only lens in the second lens group 436, in the area of maximum divergence of the beam diameter and in the area of a point of inflection of the marginal ray height. There are no negative lenses with a scattering effect that is significant for the optical design between this

entry surface and the aperture diaphragm A, or between the aperture diaphragm and the image plane. In particular, only positive lenses are provided between the entry surface E and the image plane.

If there are no negative lenses with a significant refractive power in the region in which the beam diameter is relatively large then this allows the maximum diameters of the lenses to be limited to practicable sizes in this region. "Relatively large beam diameter" for the purposes of this application occur in particular when the marginal ray height on a lens is at least as large as half the marginal ray height at a potential diaphragm position, for example at the system diaphragm. This measure takes account of the fact that the scattering effect of a negative lens may admittedly be desirable for correction reasons, but that any scattering effect downstream from the negative lens has a tendency to lead to larger lens diameters than will be necessary in the absence of a negative lens. Furthermore, the rays of the beam are joined together in the direction of the downstream image plane, and positive refractive power is required for this purpose. The positive lenses which are required for this purpose may overall be designed relatively moderately provided that there is also no need to compensate for the scattering effect of negative lenses in the combination of the beams. Furthermore, the number of lenses may be limited. The invention thus allows compact projection objectives with minimal lens dimensions.

Fig. 5 shows one embodiment of a projection objective 500 which, from the optical point of view, is designed on the basis of the principles explained with reference to Fig. 2. Identical or corresponding elements or element groups are annotated with the same reference symbols as in Fig. 2, increased by 300.

A comparison between the beam profiles in the systems shown in Fig. 2 and Fig. 5 shows that different beam paths are possible within the scope of the invention. An uncrossed beam path is shown in the system in Fig. 2, since a first beam section which runs from the object plane to the concave

mirror 225 and a second beam section which runs from this concave mirror to the image plane do not intersect anywhere. The embodiment shown in Fig. 5, in contrast, has a crossed-over beam path. The first folding mirror 513 is arranged on the side of the optical axis 504 facing away from the second folding mirror 523, with the second folding mirror being geometrically located closer to the object plane. In consequence, a first beam section 540 which runs from the object plane 501 to the concave mirror 525 and a second beam section 550 which runs from the concave mirror 525 via the second folding mirror 523 to the image plane cross over in the region immediately upstream of the mirror surface of the second folding mirror 523, in the vicinity of the intermediate images 511, 521. In this case, the second intermediate image 521 is located optically immediately before the second folding mirror 523, and geometrically in the vicinity of an inner mirror edge 528, which faces the optical axis 504, of the first folding mirror. This crossed beam path, in which the radiation is "forced by" the first folding mirror without any vignetting in the direction of the second folding mirror, in the region of the inner mirror edge 528, allows optimization of the light conductance value of the system. It also provides more physical space for the two folding mirrors.

In this embodiment as well, the positive field lens group 526 is located in the optical vicinity of both intermediate images, geometrically between the folding mirrors and the concave mirror, although the second folding mirror and the second intermediate image are somewhat further away from the positive lens 526.

One embodiment of a projection objective 600 will be explained with reference to Fig. 6, in which a pattern which is arranged on its object plane 601 is imaged on an image plane 602 aligned parallel to the object plane, generating two real intermediate images 611, 621. The projection objective has a first, catadioptric objective part 610 which produces a first real intermediate image 611 of the object field, a subsequent, catadioptric second objective part 620, which images the first intermediate image to form a second

real intermediate image 621, and a subsequent third, refractive objective part, which images the second intermediate image 621 directly, that is to say without any further intermediate image, on the image plane 602.

One major difference from the embodiments described so far is that the first objective part 610 is a compact catadioptric subsystem. The catadioptric objective part 610 has a concave mirror 615 whose optical axis is at right angles to the object plane, and a polarization-selective beam splitter 660 (Beamsplitter Cube, BSC) which is arranged between the object plane and the concave mirror and has a planar beam splitter surface 613 which is inclined at 45° to the optical axis 604 and is used as a first folding mirror for the projection objective 610. A λ/4 plate 661, a first positive group 662, a second positive group 663, the beam splitter 660, a further λ/4 plate 664 and a negative group 665 arranged immediately in front of the concave mirror are arranged in this sequence between the object plane and the concave mirror. This is followed by a further λ/4 plate 666 and a positive group 667 in the beam path downstream from the folding mirror 613. The basic configuration of the second, catadioptric objective part 620 with a positive group 626 close to the field corresponds essentially to the basic design shown in Fig. 2. The third, refractive objective part has only positive groups between which a diaphragm position is located.

In this exemplary embodiment, folding thus takes place within the first, catadioptric objective part, with positive refractive power in the form of at least one positive lens 667 being arranged between the folding mirror 613, which is responsible for this, and the first intermediate image 611, which is produced by the first subsystem. The overall system is operated with circularly polarized input light, which is converted by the first λ/4 plate to linear-polarized radiation, which is p-polarized with respect to the obliquely positioned beam splitter layer 613 and thus essentially completely passes through it to the concave mirror 650. The λ/4 plate which is arranged between the beam splitter layer and the concave mirror is passed through twice by the linear-polarized radiation and in the process rotates the polari-

zation preferred direction through 90° such that the radiation arriving from the concave mirror at the polarization splitter layer 613 is s-polarized with respect to this, and is reflected in the direction of the subsequent objective parts. The third λ/4 plate 666 converts the radiation to circularly polarized radiation, which then passes through the subsequent subsystems.

Since the first, catadioptric objective part 610 can be designed such that, in conjunction with the mirror curvature and the negative refractive power upstream of the mirror, it can largely or completely correct both the image field curvature and the chromatic longitudinal aberration, the subsequent partial objectives are not loaded, or are only slightly loaded, by these imaging errors. Furthermore, this arrangement allows the physical space between the object plane and the horizontally aligned, catadioptric objective part 620 to be enlarged, which can be used in order to reduce the light connductance value.

The aperture diaphragm A is preferably arranged in the third objective part 630, which is closest to the image, where the chief ray intersects the optical axis. Two further possible diaphragm positions are shown in the first and second objective part, in each case close to the concave mirrors 615, 625.

The first objective part may be physically compact. Fig. 7 shows an embodiment of a catadioptric subsystem which can be used as the first objective part 610 for the system shown in Fig. 6, and whose specification is shown in Table 5. Identical or corresponding elements or element groups are annotated with the same reference symbols as in Fig. 6, increased by 100. All the lenses are spherical, and all the transparent components including the beam splitter block 760 are composed of synthetic quartz glass.

Fig. 8 shows various implementation options, schematically, for the folding mirrors which are provided for folding the beam path. The folding mirrors may, for example, be in the form of free-standing planar mirrors, in particular as front surface mirrors (Figs 8(a) and (b)). In this case, in the embodi-

ments shown in Fig. 2, separate mirrors as shown in Fig. 8(b) can be held jointly, as well. The folding mirrors may also be in the form of free-standing prisms, as shown in Figs 8(c) and (d). The reflective prism surfaces may, if required, act as total internal reflection surfaces depending on the incidence angles that occur on them, or may have a reflection coating. In particular for the embodiments shown in Figs 2 to 4, the mirrors may also be in the form of reflective outer surfaces of a mirror prism as shown in Fig. 8 (e).

In Fig. 9 a further embodiment of a projection objective 900 having R-C-R-type as explained in connection with Fig. 2 is shown. Reference is made to that description for the basic construction. A first, refractive objective part 910 is designed to image an off-axis effective object field OF arranged in the object surface 901 onto a first intermediate image 911. A first planar folding mirror 913 is arranged within the first objective part immediately upstream of the first intermediate image. A second, catadioptric objective part 920 including a concave mirror 925 is designed for imaging the first intermediate image into a second intermediate image 921 positioned immediately upstream of a second folding mirror 923 at a distance therefrom. A third, refractive objective part 930 including a freely accessible aperture stop AS is designed to image the second intermediate image onto the image surface 902, where an effective image field IF arranged outside the optical axis is created. The first objective part 910 serves as a relay system to place the first intermediate image close to the first folding mirror 913. The catadioptric second objective part 920 includes a single positive lens (field lens 926) geometrically close to the folding mirrors and optically close to both intermediate images, thereby allowing efficient correction of field related imaging errors. The third objective part serves as a focussing lens group providing the major part of the reduction ratio of the projection objective to obtain the image side numerical aperture, which is NA = 1,20 in this embodiment at a field size of 26 mm • 5,5 mm of the effective object field OF. The overall track length (axial distance be-

tween object surface 901 and image surface 902) is 1400 mm. The wavefront aberration is about 4 mλ rms. The specification is given in tables 9, 9A. The chief ray CR of the imaging is drawn bold to facilitate following trajectory of the chief ray.

The lenses of the first objective part 910 define a first part OA1 of the optical axis, which is the axis of rotational symmetry of the lenses and is perpendicular to the object surface 901. The axis of rotational symmetry of the concave mirror 925 and the lenses of the second objective part define a second part OA2 of the optical axis which, in this embodiment, is aligned perpendicular to the object side first part OA1 of the optical axis. With other words, the optical axis is folded by the first folding mirror 913 at 90°. The lenses of the third objective part 930 define a third part OA3 of the optical axis, which is parallel to the first part OA1 of the optical axis and perpendicular to the image surface 902. In this embodiment, the object-side first part OA1 of the optical axis and the image-side third part OA3 of the optical axis are coaxial such that no lateral axis offset exists between these parts of the optical axis. This construction may be desireable with regard to mounting of the lenses of the refractive objective parts. A similar construction with coaxial first and third parts OA1, OA3 of the optical axis is shown as projection objective 1000 in Fig. 10. The specifcation of that design is given in table 10, 10A. In both embodiments a finite value for the object-image-shift OIS exists.

In the projection objective 900 the lens surface ASP immediately upstream of the first folding mirror 913 is an aspheric surface, which is optically close to the first intermediate image. Efficient correction of field related imaging errors are obtained. In the projection objective 1000 the field lens 1026 has an aspheric lens surface ASP facing the concave mirror. This aspheric surface is the lens surface closest to both the first and second intermediate image 1011, 1021

and therefore very effective for correction at two positions along the beam path. The wave front aberration of this design is about 3mλ rms.

The embodiment of a projection objective 1100 shown in Fig. 11 (specification in tables 11, 11A) is an example to demonstrate that practical advantages can be obtained in preferred embodiments if a lateral axis offset AO between the first part OA1 of the optical axis on the object side and a third part OA3 of the optical axis on the image side is adjusted appropriately. In order to facilitate understanding of the terms used in the following, Fig. 11' shows a schematic drawing where important features and parameters are shown.

From an optical point of view, an off-axis effective object field OF is imaged by the first objective part 1110 into a first intermediate image 1111 arranged between a first folding mirror 1113 and a positive field lens 1126 of the second objective part 1120. The second objective part includes the concave mirror 1125 and is designed as an imaging subsystem to create a second intermediate image 1121 positioned between positive lens 1126 and a second folding mirror 1123. The third objective part 1130 serves as a focussing group to generate the off-axis effective image field IF at a very high image-side numerical aperture NA, wherein here NA = 1.30.

In contradistinction to the embodiments of Figs 9 and 10 the folding prism forming with perpendicular planar faces the first and second folding mirrors is used asymmetrically, whereby a lateral axis offset AO is obtained between the first part OA1 of the optical axis on the object side and the third part OA3 of the optical axis on the image side (see Fig. 11'). In this particular embodiment the axis offset AO is set in such a way that an object field center axis OFCA running parallel to the first part OA1 of the optical axis through the object field center and an image field center axis IFCA running through the

center of the image field IF and parallel to the third part OA3 of the optical axis coincide (are coaxial). With other words, there is no object-image-shift (OIS) between the centers of the effective object field OF and image field IF. This property is usually not obtained in catadioptric projection objectives with off-axis object field, but only in projection objectives having an effective object field centered around the optical axis (e.g. purely refractive objectives or catadioptric objectives having a physical beam splitter or objectives with pupil obscuration). As evident from Fig.11' the amount of lateral axis offset AO is to be set such that the sum of the lateral axis offset AO and an image field center height h' is equal to the object field center hight h if OIS = 0 is desired. In that case:

$$|AO| = |h^*(1+|\beta|)|$$

Another beneficial aspect of preferred embodiments of the invention relates to an appropriate selection of positive refractive power for the field lens. As will be demonstrated examplarily in the following, a proper selection of refractive power allows to manufacture projection objectives with very high image side numerical apertures, such as NA = 1,3 or NA = 1,35, while maintaining a maximum size of lenses upstream and/or downstream of the folding mirrors and the overall track length of the projection objective moderate. For demonstation purposes, Fig. 12 shows a variant of a prior art projection objective of type R-C-R as shown in WO 2004/019128 having an image side numerical aperture NA = 1,25 and 1250 mm track length, which is smaller than the track length of the related prior art objective (1400 mm, Fig. 19 in WO 2004/019128 A1). There is no field lens geometrically between the folding mirrors and the concave mirror.

For comparison, Fig. 13 shows a projection objective 1300 as an embodiment of the invention, having the same numerical aperture (NA = 1,25) and track length (1250 mm), where a positive field lens

1326 is positioned geometrically between the folding mirrors 1313, 1323 and the concave mirror 1325. To facilitate comparison, schematic Fig. 14 shows a prior art system without field lens in (a) and an embodiment of the invention including a field lens FL in (b). The trajectory of a chief ray CR is drawn and bold in Figs. 12 and 13 and also outlined in Fig. 14 where, in addition, the trajectory of a marginal ray MR is shown.

Next, some characteristic features of prior art systems related to the embodiment of Fig. 12 are summarized using the reference identifications of Fig. 14(a). The first objective part is a refractive relay group L1 designed to create the first intermediate image IMI1 close to the first folding mirror FM1 of the folding prism. An axially compact (short) catadioptric second objective part including the concave mirror CM creates the second intermediate image IMI2 close to the second folding mirror FM2. A purely refractive main focussing group L2 formed by the third objective part forms the image.

The first objective part is subdivided into a first lens group LG1 and a second lens group LG2 (each positive refractive power), a pupil surface being positioned between these lens groups where the chief ray CR intersects the optical axis OA. The third objective part includes, in that sequence, a third lens group LG3 with positive refractive power, a fourth lens group LG4 with negativ refractive power, and a fifth lens group LG5 with positive refractive power. An image side pupil surface is positioned in the third objective part where the chief ray crosses the optical axis. An aperture stop AS is usually positioned at this position. A pupil surface optically between the first and second intermediate image is positioned close to or at the concave mirror CM.

Alternatively an aperture stop may also be positioned in one of the other pupil surfaces, namely in the refractive relay group L1 or in the catadioptric group, close to the concave mirror.

The chief ray CR is convergent at the first intermediate image IMI1 and the first folding mirror optically close to that interemediate image. Here, a convergent chief ray is a chief ray where the chief ray height CRH, i.e. the radial distance between the chief ray and the optical axis, is decreasing in light propergation direction. On the other hand, the chief ray is divergent (i.e. chief ray height increasing in light propergation direction) at the second intermediate image IMI2 and the second folding mirror.

Due to the folding geometry having the intermediate images between the folding mirrors and the concave mirror, the lenses of the second lens group LG2 and the third lens group LG3 closest to the first intermediate image and the second intermediate image, respectively, are optically relatively far away from the intermediate images since the folding mirror is placed between these lenses and the intermediate images. As a consequence of the convergence/divergence of the chief ray these lenses closest to the folding mirrors have a tendency to become large (large lens diameter). Note that this effect may be weaker if a larger distance is set between the concave mirror and the folding mirrors, thereby forming a longer horizontal arm (HOA) of the objective.

Given these conditions, there is a tendency for the horizontal optical axis to become shorter if the image side numerical aperture NA is to be increased. This can be understood as follows. The primary purpose of the concave mirror is to correct the Petzvalsum (image field curvature) of the projection objective. The contribution of the concave mirror for Petzval sum correction is directly proportional to the curvature of the concave mirror. If the numerical aperture of the sys-

tem is to be increased and, at the same time, the length of the horizontal arm HOA would remain constant, the diameter of the catadioptric group including the concave mirror would be increased. One potential consequence is that the curvature of the concave mirror would become smaller, whereby the effect of the concave mirror on Petzval sum correction would decrease. This is considered less desireable since the Petzval sum correction must then be provided in other parts of the projection objective, thereby making the design more complicated.

On the other hand, if it desired to maintain the correcting effect of the catadioptric group on Petzval sum correction, the diameter of the catadioptric group including the concave mirror should be maintained essentially constant. This, however, corresponds to a decreasing length of the horizontal arm which, in turn, leads to relatively large chief ray angles at the intermediate images, as shown schematically in Fig. 14(a) and in the projection objective 1200 of Fig. 12.

It is evident from Fig. 12 that very large lens diameters are required particularly for the two or three positive lenses of the second lens group LG2 immediately upstream of the first folding mirror.

However, if it is desired to increase the numerical aperture, sufficient space for lenses must be provided in the third objective part, mainly in the vincinity of the closest pupil position next to the wafer. If it is further desired to limit the track length of the objective to reasonable values, it appears that it is desireable to design the first objective part (relay group L1) axially shorter and to decrease the diameters of the lenses immediately upstream of the first folding mirror.

These objects can be obtained by introducing a field lens having sufficient positive refractive power geometrically between the folding

mirrors and the concave mirror optically close to the intermediate images, as shown schematically in Fig. 14(b) and exemplarily in embodiment 1300 of Fig. 13. As evident from Fig. 13, the positive refractive power provided by a lens 1326 allows to guide the chief ray CR almost parallel to the optical axis or slightly divergent onto the first folding mirror 1313, whereby the diameters of the two or three lenses immediately upstream of the first folding mirror can be substantially reduced when compared to the design of Fig. 12. Also, the first axial length AL1 of the first objective part 1310 is substantially reduced when compared to the corresponding length of the first objective part 1210 in Fig. 12. As a consequence, more space is available in the third objective part for introducing lenses contributing to an increase in numerical aperture. Also, the horizontal arm including the concave mirror is substantially longer and the concave mirror is substantially smaller when a field lens is introduced.

In the embodiment of Fig. 13, it is also evident that both the first and second intermediate image are positioned in a space between the field lens 1326 and the mirror group including the concave mirror 1325. Specifically, an axial distance between the intermediate images and the closest optical surface (lens surface of positive lens 1326 facing the concave mirror) is sufficiently large such that the closest optical surface lies outside an intermediate image space defined axially between the paraxial intermediate image (intermediate image formed by paraxial rays) and the marginal ray intermediate image (formed by marginal rays of the imaging). A minimum distance of at least 10 mm is obtained here. The field lens is effective as a last lens of the first objective part 1310 and as a first lens of the third objective part 1330 (when viewed in light propagation direction at the intended use as reduction projection objective). Therefore, it is worth to note that Fig. 13 shows a projection objective having two refractive imaging subsystems (formed by the first objective part 1310 and the third objective part 1330), where a lens (the field lens

1326) is arranged optically within both the first and the third imaging subsystem. Also, each folding mirror is positioned inside a refractive imaging subsystem between lenses of the respective subsystem.

The embodiments of the following Figs. 15 to 17 (specifications in tables 15, 15A, 16, 16A and 17, 17A, respectively) are based on the embodiment of Fig. 13 and show exemplarily that a basic design having a field lens with sufficient refractive power allows to obtain even higher image side numercial apertures with moderate lens sizes. The specifications are given in tables 15, 15A, 16, 16A and 17, 17A, respectively.

An image side numerical aperture NA = 1,30 is obtained for the projection objective 1500 in Fig. 15. Here, the chief ray CR is almost parallel to the optical axis at the first and second folding mirror. Specifically, a first chief ray direction cosine |CRA1| = 0.055 is obtained at the first folding mirror and a second chief ray direction cosine CRA2 = 0.058 is obtained at the second folding mirror.

In the projection objectives 1300 and 1500, the positive field lens 1326, 1526 in the horizontal arm is arranged very close to the folding mirrors such that intermediate images follow within a space free of optical material between that field lens and the concave mirror. However, as evident from the intersecting lens symbols, one or more truncated lenses must be used close to the folding mirrors, which makes lens mounting more complicated.

Such mounting problem is avoided for the projection objective 1600 in Fig. 16, where the positive field lens 1626 is positioned far away from the folding mirrors 1613, 1623 mostly outside a cylindrical space defined between the lenses immediately upstream and downstream of the folding mirrors. In this embodiment, circular lenses with a stable mounting technique can be used. From an optical point

of view, the chief ray angles at the first and second folding mirrors are almost zero (essentially telecentric chief ray). As both intermediate images 1611 and 1621 are positioned essentially between the folding mirrors and the field lens 1626, the field lens is now part of the catadioptric second imaging objective part 1620 including the concave mirror 1625. In this variant, the installation space problem close to the folding mirror is avoided. An image side numerical aperture NA = 1,30 is obtained.

The design type has potential for even higher numerical apertures, which is evident from projection objective 1700 shown in Fig. 17 having an image side numerical aperture NA = 1,35. Like in the embodiment of Fig. 16, the chief ray is almost telecentric at the folding mirrors and the intermediate images 1711, 1721 are essentially positioned between the folding mirrors and the field lens 1726. The increase in numerical aperture with respect to the embodiment of Fig. 16 shows that in that embodiment sufficient space for further and/or stronger lenses is available in the third objective part responsible for providing the high numerical aperture.

As mentioned earlier, the invention allows to built catadioptric projection objectives with high numerical aperture, particularly allowing immersion lithography at numerical apertures NA > 1, that can be built with relatively small amounts of optical material. The potential for small material consumption is demonstrated in the following considering parameters describing the fact that particularly compact projection objectives can be manufactured.

Generally, the dimensions of projection objectives tend to increase dramatically as the image side numerical aperture NA is increased. Empirically it has been found that the maximum lens diameter D_{max} tends to increase stronger than linear with increase of NA according to $D_{max} \sim NA^k$, where $k > 1$. A value $k = 2$ is an approximation used

for the purpose of this application. Further, it has been found that the maximum lens diameter D_{max} increases in proportion to the image field size (represented by the image field height Y', where Y' is the maximum distance between an image field point and the optical axis). A linear dependency is assumed for the purpose of the application. Based on these considerations a first compactness parameter COMP1 is defined as:

$$COMP1 = D_{max}/(Y' \cdot NA^2).$$

It is evident that, for given values of image field height and numerical aperture, the first compaction parameter COMP1 should be as small as possible if a compact design is desired.

Considering the overall material consumption necessary for providing a projection objective, the absolute number of lenses, N_L is also relevant. Typically, systems with a smaller number of lenses are preferred to systems with larger numbers of lenses. Therefore, a second compactness parameter COMP2 is defined as follows:

$$COMP2 = COMP1 \cdot N_L.$$

Again, small values for COMP2 are indicative of compact optical systems.

Further, projection objectives according to preferred embodiments of the invention have at least three objective parts for imaging an entry side field surface into an optically conjugate exit side field surface, where the imaging objective parts are concatenated at intermediate images. Typically, the number of lenses and the overall material necessary to build an projection objective will increase the higher the number N_{OP} of imaging objective parts of the optical system is. It is desirable to keep the average number of lenses per objective

part, N_L / N_{OP}, as small as possible. Therefore, a third compactness parameter COMP3 is defined as follows:

$$COMP3 = COMP1 \cdot N_L / N_{OP}.$$

Again, projection objectives with low optical material consumption will be characterized by small values of COMP3.

Table 18 summarizes the values necessary to calculate the compactness parameters COMP1, COMP2, COMP3 and the respective values for these parameters for each of the systems presented with a specification table (the table number (corresponding to the same number of a figure) is given in column 1 of table 18). Therefore, in order to obtain a compact catadioptric projection objective having at least one concave mirror and at least two imaging objective parts (i.e. at least one intermediate image) at least one of the following conditions (1) to (3) should be observed:

(1) COMP1 < 11

Preferably COMP1 < 10,7 should be observed.

(2) COMP2 < 340

Preferably COMP2 < 320, more preferably COMP2 < 300 should be observed.

(3) COMP3 < 110

Preferably COMP3 < 100 should be observed.

In some embodiments COMP1 < 11 and, at the same time, COMP2 < 340, which allows particularly compact designs.

Another aspect concerns the size of the concave mirror, which is particulaly small in relation to the largest lenses in some embodiments, thereby facilitating manufacturing and mounting. In some embodiments the concave mirror has a mirror diameter D_M, the projection objective has a maximum lens diameter D_{max}, and the condition $D_M < 0{,}75 * D_{max}$ holds. Preferably $D_M < 0{,}70 * D_{max}$ may be fulfilled.

Table 18 shows that preferred embodiments according to the invention generally observe at least one of these conditions indicating that compact designs with moderate material consumption and/or small concave mirror are obtained according to the design rules laid out in this specification.

The invention has been described in detail using examples of R-C-R type catadioptric projection objectives having a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane. The invention can also be implemented in designs having different folding geometry, for example those where radiation coming from the object plane is directly directed at the concave mirror prior to a reflection on a first folding mirror arranged for deflecting the radiation coming from the concave mirror in the direction of the image plane. In those embodiments, a second folding mirror is usually provided downstream of the first folding mirror to allow a parallel arrangement of object plane and image plane.

It is self-evident that all of the systems described above may be complete systems, that is to say systems for forming a real image (for example on a wafer) of a real object (for example a photolithography mask). The systems may, however, also be used as subsystems for larger systems. For example, the "object" of one of the systems described above may thus be an image which is produced by an imaging system (for example a relay sys-

tem) positioned upstream of the object plane. An image which is formed by one of the systems described above may likewise be used as an object for a system (for example a relay system) downstream from the image plane. The enumeration of the objective parts with the expressions "first objective part" and "second objective part" etc. relates to the sequence in which the beam passes through them when they are used as a reduction objective. The expressions "first" and "second" etc. should be understood as being relative to one another. The "first" objective part is arranged upstream of the "second" objective part in the direction in which the beam passes through them. This need not necessarily be the first objective part in the overall system, that is to say the objective part which immediately follows the image plane in the system. However, this is the case in the illustrated exemplary embodiments.

Table 1

NA = 1.2 Y = 57.7 mm

WL	157.2852	157.2862	157.2842
CAF2	1.55930394	1.55930133	1.55930655
IMM	1.37021435	1.37021206	1.37021665

Surface	Radius	Distance	Material	½ Diameter
0	0.000000000	48.029632171	AIR	57.700
1	0.000000000	39.172776328	AIR	72.768
2	-96.971407438	43.719958386	CAF2	74.418
3	-158.002766036	5.165244231	AIR	98.534
4	781.518257267	56.238731708	CAF2	120.188
5	-253.290501301	4.909571912	AIR	123.211
6	288.016848173	49.396794919	CAF2	124.172
7	-435.168087157	26.736905514	AIR	122.368
8	105.910945049	62.394238960	CAF2	94.783
9	178.598362309	79.753912118	AIR	79.042
10	-274.352911686	15.001130830	CAF2	42.116
11	-481.511902624	46.498544862	AIR	46.787
12	-70.442117850	52.555341121	CAF2	55.942
13	-90.455727573	1.806830035	AIR	78.160
14	3232.255140950	36.176140320	CAF2	91.116
15	-186.488036306	1.000000000	AIR	92.734
16	365.731282758	20.809036457	CAF2	90.268
17	-2611.121142850	101.825417590	AIR	88.935
18	0.000000000	0.000000000	AIR	84.274
19	0.000000000	65.181628952	AIR	84.274
20	258.735107311	37.578859051	CAF2	105.187
21	-1152.159158690	288.921175238	AIR	104.969
22	-129.279458408	15.003276235	CAF2	81.991
23	-2262.350961510	56.312694509	AIR	88.341
24	-117.450410520	15.001009008	CAF2	91.957
25	-309.800170740	28.401147541	AIR	113.929
26 R	-175.988719829	0.000000000	AIR	117.602
27 R	0.000000000	28.401147541	AIR	168.871
28	309.800170740	15.001009008	CAF2	112.745
29	117.450410520	56.312694509	AIR	87.774
30	2262.350961510	15.003276235	CAF2	78.116
31	129.279458408	288.921175238	AIR	70.315
32	1152.159158690	37.578859051	CAF2	91.290
33	-258.735107311	65.181629067	AIR	91.634
34	0.000000000	0.000000000	AIR	84.438
35	0.000000000	95.566202561	AIR	84.438
36	-385.455042894	15.000000000	CAF2	93.816
37	-452.475904634	1.000000003	AIR	97.482
38	254.248242468	32.034900497	CAF2	105.601
39	5899.473023640	1.000023801	AIR	105.353
40	190.848967014	30.278271846	CAF2	104.456
41	621.351654529	138.920391104	AIR	102.039
42	-123.640610032	33.881654714	CAF2	76.579
43	158.155949669	49.867792861	AIR	80.512
44	412.757602921	47.829461944	CAF2	98.825
45	-208.949912656	17.094373280	AIR	103.896
46	-158.641772839	15.212844332	CAF2	105.038
47	-313.678744542	1.052590482	AIR	118.827
48	-829.528825093	55.527291516	CAF2	125.550
49	-184.492343437	11.796257723	AIR	129.573
50	260.696800337	37.374556186	CAF2	132.314
51	497.808165974	65.844307831	AIR	127.088
STO	0.000000000	0.000000000	AIR	127.776
53	0.000000000	-22.615444914	AIR	128.288
54	358.239917958	44.763751865	CAF2	128.404
55	-739.494996855	1.004833255	AIR	127.649
56	242.528908132	44.488018592	CAF2	121.037
57	3949.584753010	1.000094237	AIR	116.970
58	201.527861764	58.711711773	CAF2	103.897
59	-1366.391075450	1.000007100	AIR	89.104
60	62.439639631	63.828426005	CAF2	55.026
61	0.000000000	1.550000000	IMM	17.302
62	0.000000000	0.000000000	AIR	14.425

5

Table 2

Aspherical constant

Surface No.2	
K	0.0000
C1	1.90827109e-008
C2	1.04825601e-012
C3	-1.78093208e-017
C4	2.90254732e-020
C5	-9.28646308e-025
C6	9.92757252e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 7	
K	0.0000
C1	4.29834963e-008
C2	-9.32018657e-013
C3	3.88421097e-017
C4	-1.41048066e-021
C5	3.20036532e-026
C6	-2.55377630e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 12	
K	0.0000
C1	7.12539594e-008
C2	7.81169353e-012
C3	2.24285994e-016
C4	2.70399434e-019
C5	-5.33658325e-023
C6	1.07824675e-026
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 17	
K	0.0000
C1	3.44530878e-008
C2	-3.20209778e-013
C3	4.32090602e-018
C4	3.71891782e-022
C5	-2.41461999e-026
C6	6.86020285e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 20	
K	0.0000
C1	5.99206839e-009
C2	-2.26778093e-013
C3	-5.52734742e-019
C4	3.37919534e-022
C5	-2.42416300e-026
C6	5.56746821e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 22	
K	0.0000
C1	6.63814399e-008
C2	1.50151781e-012
C3	3.42715896e-017
C4	1.13418489e-020
C5	-1.20800658e-024
C6	1.36760067e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 31	
K	0.0000
C1	-6.63814399e-008
C2	-1.50151781e-012
C3	-3.42715896e-017
C4	-1.13418489e-020
C5	1.20800658e-024
C6	-1.36760067e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. .33	
K	0.0000
C1	-5.99206839e-009
C2	2.26778093e-013
C3	5.52734742e-019
C4	-3.37919534e-022
C5	2.42416300e-026
C6	-5.56746821e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.41	
K	0.0000
C1	3.02036913e-008
C2	-8.49897291e-013
C3	-2.62757380e-018
C4	2.42290737e-021
C5	-1.80384886e-025
C6	4.40130958e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.42	
K	0.0000
C1	1.57083344e-007
C2	-5.70047014e-012
C3	9.96269363e-016
C4	-9.51074757e-020
C5	2.78023503e-024
C6	2.11268686e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.44	
K	0.0000
C1	-6.63114425e-008
C2	1.06389778e-012
C3	-1.73700448e-016
C4	7.83565903e-021
C5	-3.69851418e-025
C6	6.43100123e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 51	
K	0.0000
C1	3.97980700e-008
C2	-1.14363396e-015
C3	2.12173627e-019
C4	-1.81177143e-022
C5	-9.65440963e-027
C6	3.69511989e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 59	
K	0.0000
C1	3.28933356e-008
C2	-4.67953085e-013
C3	1.96156711e-017
C4	1.01627452e-022
C5	-3.59201172e-026
C6	2.16163436e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

5

Table 3

NA = 1.1 Y = 57.7 mm

WL	157.2852	157.2862	157.2842
CAF2	1.55930394	1.55930133	1.55930655

Surface	Radius	Distance	Material	½ Diameter
0	0.000000000	47.596241819	AIR	57.700
1	0.000000000	21.484078486	AIR	71.361
2	-130.196528296	81.232017348	CAF2	71.411
3	-201.970612192	1.090292328	AIR	102.064
4	0.000000000	43.035190104	CAF2	111.239
5	-219.688636866	1.000008083	AIR	113.511
6	196.835177454	48.645753259	CAF2	112.440
7	-1062.563638620	1.011278327	AIR	109.626
8	102.486371771	51.257817769	CAF2	88.766
9	125.152226832	78.537765316	AIR	72.052
10	-276.036111675	19.246024827	CAF2	35.565
11	-344.559129459	44.417965355	AIR	42.153
12	-73.158562407	46.803238343	CAF2	53.934
13	-81.595671547	1.005611042	AIR	71.774
14	917.859457951	35.862144308	CAF2	83.802
15	-184.688054893	1.002179985	AIR	85.191
16	520.342292054	23.034106261	CAF2	82.478
17	-768.099839930	99.999802859	AIR	80.816
18	0.000000000	0.000000000	AIR	72.928
19	0.000000000	49.999962118	AIR	72.928
20	241.487091044	30.190977973	CAF2	85.575
21	-1164.355916310	264.025266484	AIR	85.757
22	-132.516232462	15.000193519	CAF2	81.831
23	-1356.484422410	61.385058143	AIR	89.265
24	-108.588059874	14.999993604	CAF2	92.698
25	-296.429590341	28.045104017	AIR	119.543
26 R	-171.604551151	0.000000000	AIR	121.617
27 R	0.000000000	28.045104017	AIR	187.566
28	296.429590341	14.999993604	CAF2	118.640
29	108.588059874	61.385058143	AIR	87.692
30	1356.484422410	15.000193519	CAF2	75.436
31	132.516232462	264.025266484	AIR	68.614
32	1164.355916310	30.190977973	CAF2	79.925
33	-241.487091044	49.999914356	AIR	79.985
34	0.000000000	0.000000000	AIR	73.069
35	0.000000000	107.612168038	AIR	73.069
36	-693.184976623	16.117644573	CAF2	81.276
37	-696.986438150	2.228062889	AIR	84.557
38	272.001870523	26.851322582	CAF2	90.453
39	-11518.014964700	1.683452367	AIR	90.747
40	204.924277454	41.781211890	CAF2	91.627
41	3033.528484830	106.582128113	AIR	88.228
42	-134.400581416	22.683343530	CAF2	70.595
43	149.085276952	30.111359058	AIR	72.323
44	-1571.459281550	66.592767742	CAF2	74.527
45	-685.256687590	11.096249234	AIR	101.072
46	-661.646567779	85.751986497	CAF2	106.788
47	-157.414472118	1.578582665	AIR	121.872
48	281.442061787	38.097581301	CAF2	126.470
49	2477.671193110	77.916990124	AIR	123.978
50	0.000000000	0.000000000	AIR	117.805
51	0.000000000	-4.224796803	AIR	118.082
52	629.850672554	48.195853438	CAF2	118.380
53	-440.009879814	0.999978780	AIR	118.034
54	243.613408298	52.262412712	CAF2	109.822
55	11973.088705700	1.027491789	AIR	101.920
56	115.269169988	60.712228046	CAF2	83.889
57	372.135519803	1.030688086	AIR	63.468
58	72.776794128	53.208894511	CAF2	48.890
59	0.000000000	0.000000000	CAF2	14.425
60	0.000000000	0.000000000	AIR	14.425

Table 4

Aspherical constants

Surface No. 2	
K	0.0000
C1	-4.90420246e-011
C2	7.22127484e-014
C3	1.72996941e-017
C4	-3.83158229e-021
C5	1.65903133e-024
C6	-1.68929866e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No. 7	
K	0.0000
C1	2.96559302e-008
C2	-4.45892297e-013
C3	1.35851832e-017
C4	-9.75107227e-022
C5	6.40021152e-026
C6	-9.93085086e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.12	
K	0.0000
C1	6.82301843e-008
C2	6.13339976e-012
C3	-1.47536226e-016
C4	-7.56092252e-020
C5	1.52586945e-023
C6	-1.35801785e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.17	
K	0.0000
C1	4.47108229e-008
C2	-4.00171489e-013
C3	4.13032418e-018
C4	6.29956500e-022
C5	-3.85978221e-026
C6	2.31708241e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.20	
K	0.0000
C1	2.82365956e-009
C2	-3.11781699e-013
C3	-1.69631649e-018
C4	1.14900242e-021
C5	-1.52629451e-025
C6	8.81503206e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.22	
K	0.0000
C1	6.25856212e-008
C2	9.37857950e-013
C3	3.67635940e-017
C4	8.35698619e-021
C5	-1.33482892e-024
C6	1.38831758e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.31	
K	0.0000
C1	-6.25856212e-008
C2	-9.37857950e-013
C3	-3.67635940e-017
C4	-8.35698619e-021
C5	1.33482892e-024
C6	-1.38831758e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No..33	
K	0.0000
C1	-2.82365956e-009
C2	3.11781699e-013
C3	1.69631649e-018
C4	-1.14900242e-021
C5	1.52629451e-025
C6	-8.81503206e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.41	
K	0.0000
C1	2.31765306e-008
C2	-1.15108202e-012
C3	2.55992541e-017
C4	6.87393928e-022
C5	-3.66676084e-026
C6	-2.77895503e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.42	
K	0.0000
C1	1.23211770e-007
C2	-2.94099944e-012
C3	1.13325221e-015
C4	-1.09316744e-019
C5	2.28727473e-024
C6	1.03306617e-027
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.44	
K	0.0000
C1	-1.18481725e-007
C2	-2.04738790e-012
C3	-5.33930585e-016
C4	-1.51638014e-020
C5	1.67227571e-024
C6	-4.91365155e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.49	
K	0.0000
C1	2.68959500e-008
C2	-9.41267411e-014
C3	2.54969437e-018
C4	-1.50502498e-022
C5	6.35633774e-027
C6	-9.71849339e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Surface No.57	
K	0.0000
C1	3.32050996e-008
C2	4.58821096e-012
C3	-7.80384116e-016
C4	1.16466986e-019
C5	-1.04436731e-023
C6	4.66260861e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 5

NAO = 0.27 Y = 56.08 mm

WL	193.3685	193.368	193.3675
SiO22	1.56078491	1.5607857	1.56078649

Surface	Radius	Distance	Material	½ Diameter
0	0.000000000	40.000000000	AIR	56.080
1	700.000000000	30.000000000	SIO2	70.401
2	-700.000000000	1.000000000	AIR	74.095
3	700.000000000	30.000000000	SIO2	75.879
4	-700.000000000	-1.000000000	AIR	77.689
5	500.000000000	30.000000000	SIO2	78.339
6	-1000.000000000	15.000000000	AIR	78.060
7	700.000000000	30.000000000	SIO2	76.609
8	-700.000000000	0.000000000	AIR	74.839
9	0.000000000	75.000000000	SIO2	74.070
10	0.000000000	75.000000000	SIO2	64.964
11	0.000000000	13.000000000	AIR	55.857
12	-300.000000000	10.000000000	SIO2	54.317
13	-500.000000000	5.000000000	AIR	53.682
14	0.000000000	10.000000000	AIR	52.538
15	-290.000000000	0.000000000	AIR	55.162
16	0.000000000	15.000000000	AIR	54.666
17	500.000000000	10.000000000	SIO2	56.801
18	300.000000000	13.000000000	AIR	57.279
19	0.000000000	75.000000000	SIO2	58.589
20	0.000000000	75.000000000	SIO2	66.927
21	0.000000000	30.000000000	AIR	75.266
22	300.000000000	30.000000000	SIO2	82.546
23	-400.000000000	40.000100000	AIR	82.595
24	500.000000000	25.000000000	SIO2	76.453
25	-400.000000000	41.206360088	AIR	74.915
26	0.000000000	0.000000000	AIR	63.567

Table 9

SURFACE	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	59,209510			64,0
1	6291,598274	23,678332	SILUV	1,560491	85,8
2	-280,600902	1,025405			87,8
3	144,511042	32,290800	SILUV	1,560491	93,4
4	416,821920	57,132926			91,4
5	163,242835	31,337729	SILUV	1,560491	78,6
6	-661,476201	9,882827			75,2
7	85,805375	31,336035	SILUV	1,560491	59,0
8	97,841124	32,157174			46,3
9	-110,558780	50,000185	SILUV	1,560491	43,4
10	-105,568468	7,861299			62,9
11	-95,869843	33,360087	SILUV	1,560491	64,6
12	-396,465160	25,208502			89,8
13	-295,388642	49,666565	SILUV	1,560491	103,3
14	-127,525234	0,999856			109,4
15	-279,794894	36,644817	SILUV	1,560491	118,2
16	-160,830350	0,999370			121,6
17	321,280433	28,683439	SILUV	1,560491	121,8
18	1713,098384	0,999141			120,6
19	249,641678	30,928964	SILUV	1,560491	117,3
20	1775,118866	84,998661			114,7
21	0,000000	-14,998086	REFL		183,2
22	-322,738827	-22,708716	SILUV	1,560491	86,5
23	1794,276655	-198,953288			84,1
24	102,167956	-12,500000	SILUV	1,560491	72,4
25	15297,224085	-58,562725			82,5
26	106,167570	-12,500000	SILUV	1,560491	89,2
27	192,760260	-27,399192			107,8
28	154,038668	27,399192	REFL		115,3
29	192,760260	12,500000	SILUV	1,560491	107,8
30	106,167570	58,562725			89,2
31	15297,224085	12,500000	SILUV	1,560491	82,5
32	102,167956	198,954271			72,4
33	1794,276655	22,708716	SILUV	1,560491	84,1
34	-322,738827	14,999504			86,5
35	0,000000	-84,999766	REFL		179,0
36	665,918045	-20,162556	SILUV	1,560491	112,6
37	332,340267	-0,999827			115,0
38	-545,416435	-30,156611	SILUV	1,560491	121,7
39	972,309758	-0,999891			122,2
40	-239,092507	-40,367741	SILUV	1,560491	122,8
41	-3867,765964	-1,000866			121,0
42	-145,814165	-43,782811	SILUV	1,560491	108,8
43	-475,322286	-20,838629			103,7
44	994,251725	-9,999791	SILUV	1,560491	100,7
45	-102,926902	-38,025955			82,3

46	-666,254624	-9,999917	SILUV	1,560491	82,7
47	-120,991218	-38,125943			83,4
48	-444,529439	-19,995612	SILUV	1,560491	93,9
49	7256,085975	-72,078976			96,0
50	861,320622	-16,316029	SILUV	1,560491	115,4
51	367,114240	-21,532267			118,5
52	-578,781634	-19,544116	SILUV	1,560491	135,3
53	-1539,844110	-1,000064			136,2
54	-409,215581	-53,967605	SILUV	1,560491	140,1
55	388,259251	-21,190519			140,0
56	0,000000	-14,363454			131,6
57	-492,744559	-42,747305	SILUV	1,560491	135,3
58	596,175995	-0,999975			134,4
59	-188,727208	-44,971247	SILUV	1,560491	119,1
60	-1267,900423	-0,999664			114,6
61	-118,853763	-29,974419	SILUV	1,560491	90,5
62	-172,286110	-2,720285			82,2
63	-83,065857	-24,574193	SILUV	1,560491	67,0
64	-111,658319	-1,105096			56,0
65	-69,828581	-43,055955	SILUV	1,560491	50,3
66	0,000000	-1,001571	H2OV193	1,436823	20,5
67	0,000000	0,000000			19,0

Table 9A

ASPHERIC CONSTANTS

SRF	6	15	20	24
K	0	0	0	0
C1	7,168010E-08	-6,564766E-09	1,990247E-08	-1,434139E-07
C2	7,874235E-13	4,352930E-13	2,214975E-13	-3,992456E-12
C3	3,026860E-16	-2,400883E-17	-2,046213E-17	-3,265156E-16
C4	-3,434246E-20	3,866886E-22	9,725329E-22	3,104990E-21
C5	3,870353E-25	1,162444E-27	-2,756730E-26	-1,874174E-24
C6	7,234455E-29	-1,259764E-32	4,143527E-31	-4,628892E-28

SRF	43	45	47	50
K	0	0	0	0
C1	-1,007015E-08	-4,489903E-08	5,184442E-08	3,174451E-08
C2	-3,821558E-13	1,198606E-12	5,582183E-12	5,537615E-14
C3	8,872440E-17	-1,562441E-16	2,393671E-16	3,190712E-18
C4	-6,956619E-21	1,250805E-20	7,608169E-21	-6,524213E-22
C5	3,866469E-25	2,467619E-24	-1,988373E-24	-7,379838E-27
C6	-7,623750E-30	-1,675469E-28	2,670495E-28	-9,847764E-31

SRF	62	64
K	0	0
C1	6,908374E-08	-2,282295E-07
C2	-7,414546E-12	-2,062783E-11
C3	1,971662E-16	1,258799E-15
C4	-5,334580E-20	-2,146440E-19
C5	5,884223E-24	4,332875E-23
C6	-3,743875E-28	-1,189088E-27

Table 10

SURFACE	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	51,000259			64,0
1	1084,670740	20,061470	SILUV	1,560491	84,0
2	-489,591572	8,024505			85,7
3	147,977412	33,265720	SILUV	1,560491	93,2
4	533,607588	60,035648			91,5
5	162,257926	31,487872	SILUV	1,560491	79,2
6	-641,542087	12,321334			75,9
7	88,691635	37,381348	SILUV	1,560491	60,1
8	113,767960	26,723349			45,6
9	-117,888976	42,501530	SILUV	1,560491	42,0
10	-162,865349	13,700402			59,6
11	-116,482373	32,902705	SILUV	1,560491	63,1
12	-306,816392	26,438566			83,9
13	-323,530175	41,085951	SILUV	1,560491	99,9
14	-137,244758	5,556612			105,5
15	-451,636628	44,589731	SILUV	1,560491	115,9
16	-154,769207	0,999820			119,2
17	392,370175	25,008628	SILUV	1,560491	118,0
18	3014,562689	0,999723			117,0
19	289,177591	25,844242	SILUV	1,560491	114,3
20	925,962044	84,999670			112,1
21	0,000000	-14,999476	REFL		175,2
22	-331,395343	-22,607980	SILUV	1,560491	89,7
23	3332,007318	-230,559976			87,1
24	98,691313	-12,500000	SILUV	1,560491	73,1
25	28881,747267	-55,643371			84,0
26	105,777999	-12,500000	SILUV	1,560491	89,4
27	190,916612	-27,579443			109,5
28	155,323230	27,579443	REFL		118,2
29	190,916612	12,500000	SILUV	1,560491	109,5
30	105,777999	55,643371			89,4
31	28881,747267	12,500000	SILUV	1,560491	84,0
32	98,691313	230,560091			73,1
33	3332,007318	22,607980	SILUV	1,560491	87,1
34	-331,395343	14,999815			89,7
35	0,000000	-85,031452	REFL		185,4
36	632,234731	-21,937556	SILUV	1,560491	116,1
37	312,776852	-1,989523			118,6
38	-419,317799	-39,548184	SILUV	1,560491	126,0
39	679,933212	-11,879717			126,0
40	-359,055554	-33,826228	SILUV	1,560491	122,0
41	1713,588185	-6,930143			120,4
42	-130,793879	-40,665153	SILUV	1,560491	103,0
43	-297,152405	-24,525611			97,5
44	888,942670	-10,000074	SILUV	1,560491	94,8
45	-95,853886	-38,822971			77,7

46	-1286,530610	-10,502279	SILUV	1,560491	78,3
47	-122,332491	-53,312951			80,5
48	-1046,310490	-29,995767	SILUV	1,560491	98,8
49	-3155,314818	-35,731529			106,3
50	-2635,516216	-38,906996	SILUV	1,560491	121,6
51	253,216058	-1,026566			125,0
52	-477,178385	-27,726167	SILUV	1,560491	136,5
53	-1111,410551	-1,006437			137,0
54	-419,465047	-45,153215	SILUV	1,560491	138,9
55	657,652879	-27,561809			138,4
56	0,000000	11,279146			129,1
57	-1714,364190	-34,463306	SILUV	1,560491	133,1
58	435,051330	-26,422505			131,9
59	-217,425708	-40,030383	SILUV	1,560491	113,2
60	191072,918549	-0,999778			109,6
61	-106,841172	-32,593766	SILUV	1,560491	85,0
62	-202,323930	-0,999427			77,0
63	-79,299863	-25,891843	SILUV	1,560491	63,5
64	-117,061751	-0,998476			52,9
65	-70,340516	-36,868819	SILUV	1,560491	46,7
66	0,000000	-1,001571	H2OV193	1,436823	20,5
67	0,000000	0,000000			19,0

Table 10A

ASPHERIC CONSTANTS

SRF	6	15	23	24	32
K	0	0	0	0	0
C1	8,416890E-08	-2,308559E-08	-8,485003E-09	-1,223767E-07	-1,223767E-07
C2	1,006640E-12	1,109550E-13	-6,734945E-14	-7,438273E-12	-7,438273E-12
C3	3,617643E-16	-6,344353E-18	5,661979E-19	-4,704304E-16	-4,704304E-16
C4	-4,192188E-20	1,566682E-22	-2,504587E-22	3,963572E-21	3,963572E-21
C5	6,704096E-26	-4,902118E-27	2,908669E-26	-6,736661E-24	-6,736661E-24
C6	1,721955E-28	4,306889E-32	-1,350234E-30	-4,531767E-28	-4,531767E-28

SRF	33	43	45	47	50
K	0	0	0	0	0
C1	-8,485003E-09	-3,497951E-09	-4,202804E-08	6,218114E-08	3,138180E-08
C2	-6,734945E-14	-5,106017E-13	1,982600E-12	4,755456E-12	-3,924136E-13
C3	5,661979E-19	6,844726E-17	-1,463517E-16	4,467358E-16	5,657046E-18
C4	-2,504587E-22	-3,263478E-21	9,687863E-21	2,313332E-20	-6,552593E-22
C5	2,908669E-26	9,349870E-26	2,764278E-24	-3,886568E-24	2,087202E-26
C6	-1,350234E-30	2,248476E-30	7,460803E-29	4,543438E-28	-5,207993E-31

SRF	55	62	64
K	0	0	0
C1	-5,022929E-10	-2,500268E-08	-1,132630E-07
C2	-3,387071E-14	-7,360583E-12	-3,255025E-11
C3	-1,887886E-17	1,175353E-15	6,754420E-15
C4	6,061750E-22	-2,566402E-19	-9,778374E-19
C5	-8,730441E-27	2,406082E-23	6,403897E-23
C6	4,736715E-32	-1,314800E-27	1,523975E-27

Table 11

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	42,716567			63,0
1	187,082284	29,074103	SIO2	1,560491	87,7
2	1122,624300	13,704059			87,8
3	257,788495	25,970502	SIO2	1,560491	89,3
4	4087,923719	6,751806			88,2
5	149,090802	9,999268	SIO2	1,560491	84,3
6	112,190840	20,619019			79,4
7	222,671339	39,005001	SIO2	1,560491	79,4
8	-171,486868	0,999098			77,9
9	72,242638	58,534093	SIO2	1,560491	61,0
10	103,263585	23,657309			38,2
11	-120,537552	36,218695	SIO2	1,560491	39,7
12	-79,009690	13,559024			52,6
13	-70,743286	10,000301	SIO2	1,560491	55,6
14	-406,875493	15,578104			72,7
15	-167,014571	41,099022	SIO2	1,560491	76,7
16	-97,881974	0,999302			86,2
17	-289,132352	49,908319	SIO2	1,560491	102,4
18	-127,491717	0,999640			108,2
19	-915,187280	29,128849	SIO2	1,560491	114,2
20	-267,279137	70,000315			116,1
21	0,000000	-99,530888	REFL		163,4
22	-211,224346	-59,634155	SIO2	1,560491	129,3
23	847,318306	-285,786240			127,5
24	108,606993	-12,500000	SIO2	1,560491	68,7
25	-2037,814268	-40,801930			77,3
26	98,650256	-12,500000	SIO2	1,560491	79,4
27	173,699507	-12,863441			95,4
28	147,630649	12,863441	REFL		98,7
29	173,699507	12,500000	SIO2	1,560491	95,4
30	98,650256	40,801930			79,4
31	-2037,814268	12,500000	SIO2	1,560491	77,3
32	108,606993	285,786240			68,7
33	847,318306	59,634155	SIO2	1,560491	127,5
34	-211,224346	81,116047			129,3
35	0,000000	-73,612596	REFL		160,7
36	-389,330139	-33,487696	SIO2	1,560491	114,9
37	1028,934202	-0,999947			113,5
38	-174,265376	-32,363134	SIO2	1,560491	104,3
39	-396,847027	-1,000532			99,8
40	-121,243745	-48,918207	SIO2	1,560491	89,3
41	-131,171270	-29,702617			71,3
42	335,952888	-10,034790	SIO2	1,560491	69,3
43	-82,977553	-43,925742			61,4
44	142,301184	-9,999862	SIO2	1,560491	63,2
45	-263,305242	-23,458962			74,7

46	2291,125201	-61,398344	SIO2	1,560491	84,5
47	165,812687	-1,061241			103,9
48	486,553030	-37,309271	SIO2	1,560491	113,9
49	194,984003	-21,455915			120,7
50	-2153,235102	-50,329924	SIO2	1,560491	142,6
51	291,296473	-0,999132			144,8
52	-443,499291	-44,594835	SIO2	1,560491	146,7
53	1173,500711	-8,577265			145,5
54	0,000000	7,578035			138,4
55	-337,532449	-35,808358	SIO2	1,560491	139,1
56	-1836,960645	-1,165380			136,4
57	-439,395199	-28,816834	SIO2	1,560491	133,5
58	2161,178835	-0,998190			130,3
59	-260,497359	-36,004531	SIO2	1,560491	115,8
60	5382,003743	-0,997164			110,1
61	-122,176927	-36,201583	SIO2	1,560491	86,2
62	-321,548352	-1,000000			76,5
63	-54,686592	-41,835126	SIO2	1,560491	49,5
64	0,000000	-3,000000	H2O	1,436823	25,2
65	0,000000	0,000000			18,8

Table 11A

ASPHERIC CONSTANTS

SRF	8	14	19	22	25
K	0	0	0	0	0
C1	1,079370E-07	7,669220E-08	-7,045424E-09	1,010508E-08	3,738770E-08
C2	1,064327E-12	-1,973038E-11	-3,066122E-14	1,795924E-13	-3,496492E-12
C3	-4,566909E-16	2,138994E-15	-4,118337E-18	1,934995E-18	3,233016E-16
C4	1,905320E-19	-1,074179E-19	3,495758E-22	1,389960E-22	-3,498294E-20
C5	-1,972022E-23	-2,090955E-24	-2,483792E-26	-5,289985E-27	2,704951E-24
C6	8,751032E-28	4,279927E-28	4,016359E-31	1,320749E-31	-9,856748E-29

SRF	31	34	42	46	48
K	0	0	0	0	0
C1	3,738770E-08	1,010508E-08	3,117477E-08	8,249850E-08	4,142725E-08
C2	-3,496492E-12	1,795924E-13	-1,385143E-11	-1,955317E-13	-2,012061E-12
C3	3,233016E-16	1,934995E-18	2,707311E-15	-8,022466E-17	1,566310E-17
C4	-3,498294E-20	1,389960E-22	-3,351896E-19	-1,723197E-20	1,046236E-22
C5	2,704951E-24	-5,289985E-27	2,318550E-23	-8,777152E-25	3,404661E-25
C6	-9,856748E-29	1,320749E-31	-7,018917E-28	-2,800720E-28	-8,280605E-30

SRF	51	57	60
K	0	0	0
C1	3,292883E-10	4,807681E-08	3,409977E-09
C2	-7,254285E-13	-2,265563E-12	-3,641765E-12
C3	2,476488E-17	6,703492E-17	2,594792E-16
C4	-1,056859E-21	-1,704146E-21	-1,764035E-20
C5	4,966804E-26	4,472968E-26	7,777614E-25
C6	-8,485797E-31	-6,865707E-31	-1,797945E-29

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Table 12

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	35,040681			61,5
1	210,405327	30,736588	SIO2	1,560491	81,0
2	-829,214191	5,286654			81,6
3	107,948426	51,211605	SIO2	1,560491	82,3
4	81,561700	24,185596			66,5
5	129,355284	38,167801	SIO2	1,560491	67,5
6	-166,842164	0,997639			65,8
7	73,621253	52,812760	SIO2	1,560491	55,2
8	87,502326	23,343983			35,4
9	-63,355137	18,274984	SIO2	1,560491	38,4
10	-64,795456	15,650649			46,8
11	-65,436171	11,477841	SIO2	1,560491	52,6
12	-192,744558	16,904355			69,7
13	-246,808133	48,828721	SIO2	1,560491	85,8
14	-107,969356	0,997713			94,9
15	-447,790890	56,851474	SIO2	1,560491	111,1
16	-133,844748	0,997553			116,8
17	315,857486	38,321196	SIO2	1,560491	120,8
18	-1923,797869	0,996321			119,7
19	232,932637	43,497172	SIO2	1,560491	114,0
20	-887,954229	59,994922			110,5
21	0,000000	-177,093526	REFL		80,1
22	102,645236	-12,500000	SIO2	1,560491	67,0
23	942,361489	-43,357484			77,8
24	90,416551	-12,500000	SIO2	1,560491	79,9
25	149,946360	-13,736983			97,4
26	131,782255	13,736983	REFL		100,5
27	149,946360	12,500000	SIO2	1,560491	97,4
28	90,416551	43,357484			79,9
29	942,361489	12,500000	SIO2	1,560491	77,8
30	102,645236	177,093526			67,0
31	0,000000	-60,055220	REFL		75,6
32	104914,890260	-35,073765	SIO2	1,560491	98,4
33	219,963934	-0,997320			101,4
34	-485,974374	-33,321196	SIO2	1,560491	106,4
35	531,348627	-0,997416			106,7
36	-179,150861	-35,974078	SIO2	1,560491	104,0
37	-726,299833	-0,997789			101,1
38	-143,133378	-31,466370	SIO2	1,560491	92,9
39	-333,246416	-43,619093			87,4
40	149,805913	-9,999074	SIO2	1,560491	78,6
41	-96,090593	-42,639692			69,3
42	224,529027	-9,998160	SIO2	1,560491	70,5
43	-264,668390	-13,559760			81,5
44	-938,629305	-29,640517	SIO2	1,560491	87,3
45	304,621140	-22,447192			93,1

46	-943,485170	-40,752283	SIO2	1,560491	115,1
47	271,215785	-2,888195			119,3
48	-456,833471	-43,199885	SIO2	1,560491	132,8
49	693,683615	-0,999609			133,5
50	-281,164030	-30,395117	SIO2	1,560491	132,9
51	-613,816799	-6,979889			131,4
52	0,000000	4,747264			128,8
53	-323,801518	-45,333595	SIO2	1,560491	131,0
54	567,522747	-0,997957			129,5
55	-227,500831	-39,940578	SIO2	1,560491	115,7
56	2013,736081	-0,994433			111,6
57	-127,539619	-33,332450	SIO2	1,560491	88,1
58	-263,904129	-0,995386			79,4
59	-186,455700	-17,466462	SIO2	1,560491	75,0
60	-223,493619	-1,000000			65,7
61	-50,654088	-43,114607	SIO2	1,560491	46,1
62	0,000000	-1,001571	H2O	1,436823	20,2
63	0,000000	0,000000			18,4

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Table 12A

ASPHERIC CONSTANTS

SRF	6	15	20	23	29
K	0	0	0	0	0
C1	1,415105E-07	-3,894450E-08	3,025563E-08	1,956249E-08	1,956249E-08
C2	2,826103E-11	2,477873E-13	-9,725078E-13	-1,254267E-12	-1,254267E-12
C3	-2,796060E-15	-1,083388E-17	5,264859E-17	9,958049E-17	9,958049E-17
C4	-2,054534E-20	-9,685453E-22	-2,790853E-21	-1,339908E-20	-1,339908E-20
C5	2,141589E-23	4,488758E-26	1,033038E-25	1,243181E-24	1,243181E-24
C6	2,934466E-27	-1,114090E-30	-1,853921E-30	-1,590289E-29	-1,590289E-29

SRF	39	40	42	46	53
K	0	0	0	0	0
C1	-2,460699E-08	-1,818564E-07	9,053886E-08	2,136533E-08	3,430277E-08
C2	7,712743E-13	-5,379726E-12	-1,959930E-12	6,940713E-13	2,113104E-13
C3	-8,069808E-17	1,480406E-15	-3,377347E-17	-1,785783E-17	-8,054096E-17
C4	-5,118403E-22	-1,519056E-19	3,600872E-20	-1,433861E-21	3,084255E-21
C5	-4,277639E-25	1,009523E-23	-8,476096E-24	1,884530E-25	-3,491487E-26
C6	1,160028E-29	-4,043479E-28	3,114715E-28	-8,828841E-30	5,775365E-32

SRF	55	58
K	0	0
C1	2,382259E-08	9,580994E-08
C2	-8,346810E-13	-3,279417E-11
C3	1,015704E-16	5,067874E-15
C4	5,829694E-22	-5,784345E-19
C5	6,456340E-26	4,554897E-23
C6	-7,406922E-30	-1,883439E-27

Table 13

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	35,000921			64,0
1	187,873268	27,994570	SIO2	1,560491	84,8
2	1232,241084	0,999905			84,9
3	208,335351	22,691065	SIO2	1,560491	85,8
4	516,062469	36,805573			84,3
5	144,085611	11,684135	SIO2	1,560491	79,4
6	104,200976	18,908624			74,4
7	198,091293	38,252361	SIO2	1,560491	74,7
8	-192,861116	2,099088			73,3
9	68,893595	56,883996	SIO2	1,560491	61,6
10	85,948719	33,744342			40,9
11	-114,007614	22,821973	SIO2	1,560491	45,3
12	-76,222967	9,221322			52,2
13	-67,210067	9,999789	SIO2	1,560491	53,7
14	-429,663877	10,809503			70,6
15	-265,085106	43,979820	SIO2	1,560491	76,7
16	-101,149234	0,999957			85,3
17	-188,336349	61,381983	SIO2	1,560491	94,4
18	-125,228059	0,999649			108,4
19	-831,599269	31,650721	SIO2	1,560491	113,5
20	-227,778209	70,000634			115,5
21	0,000000	-10,976723	REFL		113,6
22	-197,591390	-49,195844	SIO2	1,560491	114,4
23	1113,814097	-282,271651			112,2
24	95,811897	-12,500000	SIO2	1,560491	68,9
25	1585,519591	-38,490833			81,2
26	106,142717	-12,500000	SIO2	1,560491	83,5
27	160,434031	-12,092178			98,0
28	144,603311	12,092178	REFL		101,8
29	160,434031	12,500000	SIO2	1,560491	98,0
30	106,142717	38,490833			83,5
31	1585,519591	12,500000	SIO2	1,560491	81,2
32	95,811897	282,271651			68,9
33	1113,814097	49,195844	SIO2	1,560491	112,2
34	-197,591390	10,976723			114,4
35	0,000000	-70,000758	REFL		113,0
36	-227,942708	-45,666153	SIO2	1,560491	113,9
37	815,467694	-8,857490			111,9
38	-130,706498	-42,732270	SIO2	1,560491	96,7
39	-422,473074	-3,774367			91,0
40	-347,973618	-10,000122	SIO2	1,560491	87,2
41	-187,015492	-26,831797			79,4
42	305,312838	-9,999427	SIO2	1,560491	77,7
43	-96,429310	-63,819408			67,9
44	128,506823	-9,999684	SIO2	1,560491	71,4
45	-306,117569	-15,977415			85,1
46	4806,899558	-32,925545	SIO2	1,560491	89,1
47	230,072868	-16,329646			96,4

48	1322,097164	-30,272168	SIO2	1,560491	111,8
49	252,570224	-1,000013			117,3
50	-862,460198	-42,042752	SIO2	1,560491	133,4
51	448,126973	-5,878180			135,8
52	-378,669699	-51,982596	SIO2	1,560491	142,6
53	730,087868	-26,644994			141,8
54	0,000000	0,211836			130,3
55	-454,237341	-34,638587	SIO2	1,560491	132,4
56	896,710905	-0,999763			131,1
57	-281,292658	-31,904925	SIO2	1,560491	122,1
58	-1508,491985	-0,999650			118,8
59	-157,343378	-32,737319	SIO2	1,560491	105,3
60	-431,549831	-0,998214			98,8
61	-227,748250	-34,282018	SIO2	1,560491	96,4
62	1679,133063	-1,000000			90,0
63	-57,914528	-47,987219	SIO2	1,560491	52,2
64	0,000000	-3,000000	H2O	1,436822	24,4
65	0,000000	0,000000			19,0

Table 13A

ASPHERIC CONSTANTS

SRF	8	19	22	25	31
K	0	0	0	0	0
C1	8,300393E-08	-1,573837E-08	1,023614E-08	2,221568E-08	2,221568E-08
C2	1,027628E-11	-1,239737E-13	1,645106E-13	-1,740421E-12	-1,740421E-12
C3	-1,162954E-15	4,333229E-19	5,476658E-18	8,521877E-17	8,521877E-17
C4	2,985096E-19	4,074898E-23	5,702605E-23	-2,769929E-21	-2,769929E-21
C5	-2,802134E-23	-1,053291E-26	9,144213E-28	-2,436823E-25	-2,436823E-25
C6	1,422951E-27	3,216727E-31	2,477447E-32	1,867891E-29	1,867891E-29

SRF	34	37	39	42	48
K	0	0	0	0	0
C1	1,023614E-08	-2,156946E-08	2,940607E-08	-4,027138E-08	3,236874E-08
C2	1,645106E-13	7,245612E-13	-3,554065E-12	-8,699926E-12	-3,262283E-13
C3	5,476658E-18	-3,214615E-17	2,494890E-16	1,342629E-15	2,281353E-17
C4	5,702605E-23	1,250838E-21	-1,750741E-20	-1,587155E-19	2,583318E-22
C5	9,144213E-28	-3,654841E-26	8,304704E-25	1,051342E-23	-8,007782E-27
C6	2,477447E-32	5,939707E-31	-4,233041E-29	-3,667649E-28	2,555841E-30

SRF	55	57	60
K	0	0	0
C1	2,858710E-08	-6,660513E-09	-8,504243E-08
C2	-4,529671E-13	1,798520E-13	9,820443E-13
C3	-2,789924E-17	8,149876E-17	-5,540310E-17
C4	2,259110E-21	-5,213396E-22	1,576819E-20
C5	-7,538599E-26	-1,301705E-27	-9,640368E-25
C6	9,633331E-31	-5,575917E-31	1,171801E-29

Table 15

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	35,638328			64,5
1	180,670546	28,377083	SIO2	1,560491	86,9
2	823,598018	1,194225			86,9
3	205,952639	21,462318	SIO2	1,560491	87,9
4	398,186838	32,742116			86,4
5	132,286925	9,999671	SIO2	1,560491	82,8
6	105,118100	22,332626			78,4
7	169,334381	39,894990	SIO2	1,560491	78,9
8	-204,634515	0,998375			77,3
9	71,137197	56,763393	SIO2	1,560491	63,5
10	89,028585	28,411826			42,3
11	-109,689407	29,990063	SIO2	1,560491	42,5
12	-79,244543	11,316478			52,9
13	-69,719014	9,999481	SIO2	1,560491	55,1
14	-486,086468	8,908815			72,6
15	-280,858669	63,675056	SIO2	1,560491	77,0
16	-111,752476	0,999172			95,1
17	-263,723959	47,422516	SIO2	1,560491	107,8
18	-134,607968	0,998507			113,2
19	-648,995845	28,867753	SIO2	1,560491	116,3
20	-239,623615	69,998695			118,1
21	0,000000	-9,999382	REFL		115,6
22	-176,982011	-52,138664	SIO2	1,560491	117,7
23	2325,743514	-250,507300			115,3
24	98,260574	-12,500000	SIO2	1,560491	68,0
25	8846,828964	-46,770944			78,6
26	91,149491	-12,500000	SIO2	1,560491	80,6
27	149,955261	-18,614447			98,7
28	143,121066	18,614447	REFL		106,4
29	149,955261	12,500000	SIO2	1,560491	98,7
30	91,149491	46,770944			80,6
31	8846,828964	12,500000	SIO2	1,560491	78,6
32	98,260574	250,507300			68,0
33	2325,743514	52,138664	SIO2	1,560491	115,3
34	-176,982011	9,999382			117,7
35	0,000000	-69,999093	REFL		117,4
36	-198,540813	-50,399536	SIO2	1,560491	120,7
37	-96842,830748	-0,998438			118,2
38	-171,973861	-30,749387	SIO2	1,560491	106,4
39	-310,515975	-0,999047			100,9
40	-148,789628	-29,674304	SIO2	1,560491	92,9
41	-216,223375	-29,457017			83,9
42	244,105965	-9,998957	SIO2	1,560491	81,6
43	-94,244903	-51,985700			68,7
44	177,704589	-9,999140	SIO2	1,560491	70,5
45	-255,547186	-23,809565			80,1

46	1016,476754	-31,174795	SIO2	1,560491	85,3
47	185,094367	-0,999190			93,0
48	1691,382932	-25,547970	SIO2	1,560491	105,3
49	356,397350	-45,184652			109,5
50	-673,758971	-45,536220	SIO2	1,560491	137,5
51	386,080342	-0,998330			139,3
52	-725,704793	-34,052538	SIO2	1,560491	143,2
53	1177,576128	-20,729220			143,2
54	0,000000	19,731628			138,3
55	-296,953200	-49,211938	SIO2	1,560491	142,1
56	755,844934	-0,996608			140,3
57	-413,530408	-40,022653	SIO2	1,560491	135,6
58	728,550434	-0,994509			133,1
59	-253,678570	-33,049432	SIO2	1,560491	114,4
60	-3840,733691	-0,992017			108,6
61	-147,857222	-36,663873	SIO2	1,560491	91,0
62	-727,362791	-1,000000			82,4
63	-54,588882	-41,518373	SIO2	1,560491	49,4
64	0,000000	-3,000000	H2O	1,436822	25,6
65	0,000000	0,000000			19,1

Table 15A

ASPHERIC CONSTANTS

SRF	8	19	22	25	31
K	0	0	0	0	0
C1	1,080775E-07	-1,359371E-08	1,195268E-08	1,894952E-08	1,894952E-08
C2	4,576422E-12	-1,179706E-13	3,137653E-13	-2,377925E-12	-2,377925E-12
C3	-8,540180E-16	-1,702891E-18	4,990292E-18	2,890682E-16	2,890682E-16
C4	2,711292E-19	8,483261E-23	5,081387E-22	-5,626586E-20	-5,626586E-20
C5	-3,150111E-23	-9,645405E-27	-1,599365E-26	6,907483E-24	6,907483E-24
C6	1,652368E-27	2,669817E-31	6,313609E-31	-3,643846E-28	-3,643846E-28

SRF	34	42	46	48	51
K	0	0	0	0	0
C1	1,195268E-08	-5,071114E-08	2,526230E-08	1,948430E-08	-7,924272E-09
C2	3,137653E-13	-7,730551E-12	5,333528E-12	-3,427570E-12	-2,800312E-13
C3	4,990292E-18	1,390231E-15	-2,388835E-16	8,808674E-17	-1,107739E-18
C4	5,081387E-22	-1,451491E-19	1,259420E-20	-8,959654E-22	-6,249802E-22
C5	-1,599365E-26	9,288570E-24	-1,438626E-24	8,169992E-25	3,539057E-26
C6	6,313609E-31	-2,767389E-28	4,673358E-29	-4,150555E-29	-3,955788E-31

SRF	56	57	60
K	0	0	0
C1	-5,185154E-08	2,760546E-08	2,284067E-09
C2	1,533838E-12	-1,425919E-12	-5,023236E-12
C3	-3,899899E-17	4,438919E-17	4,371011E-16
C4	2,974803E-21	1,556484E-21	-3,186523E-20
C5	-1,127749E-25	-7,877661E-26	1,530451E-24
C6	1,290864E-30	3,875637E-31	-3,713691E-29

Table 16

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	35,000018			61,5
1	176,014829	27,505489	SIO2	1,560491	83,2
2	841,641338	3,539440			83,3
3	235,708002	18,995896	SIO2	1,560491	84,2
4	435,386108	31,751453			83,2
5	145,827863	9,997737	SIO2	1,560491	81,5
6	108,756276	21,241416			77,5
7	172,246858	43,116768	SIO2	1,560491	78,7
8	-170,835113	1,011739			77,5
9	69,519772	62,982649	SIO2	1,560491	62,1
10	79,357512	24,125307			37,1
11	-105,554185	28,151777	SIO2	1,560491	40,1
12	-75,432491	8,970185			50,0
13	-65,960377	9,998436	SIO2	1,560491	51,6
14	-458,378416	15,879266			68,1
15	-182,010566	40,279435	SIO2	1,560491	74,6
16	-98,619683	0,998823			84,4
17	-298,466841	53,135226	SIO2	1,560491	100,4
18	-121,383228	0,999120			106,3
19	-835,480319	32,135277	SIO2	1,560491	109,9
20	-214,880198	81,470423			111,6
21	0,000000	-104,650759	REFL		105,0
22	-181,003736	-50,001353	SIO2	1,560491	108,2
23	25242,924145	-247,127318			104,9
24	102,272953	-12,500000	SIO2	1,560491	70,6
25	2103,060508	-45,023548			79,1
26	93,409938	-12,500000	SIO2	1,560491	81,3
27	183,538848	-17,774476			102,5
28	145,905578	17,774476	REFL		106,5
29	183,538848	12,500000	SIO2	1,560491	102,5
30	93,409938	45,023548			81,3
31	2103,060508	12,500000	SIO2	1,560491	79,1
32	102,272953	247,127318			70,6
33	25242,924145	50,001353	SIO2	1,560491	104,9
34	-181,003736	104,650759			108,2
35	0,000000	-69,997840	REFL		105,8
36	-274,353554	-38,229015	SIO2	1,560491	110,1
37	1131,690506	-0,997876			108,9
38	-183,833011	-33,580596	SIO2	1,560491	101,6
39	-632,386130	-3,643030			97,6
40	-138,532192	-34,568737	SIO2	1,560491	86,8
41	-189,656554	-26,890307			75,9
42	255,989593	-9,998587	SIO2	1,560491	73,9
43	-92,462677	-50,122191			64,9
44	175,417954	-9,998324	SIO2	1,560491	68,1
45	-239,557458	-20,895117			78,3

46	893,327075	-36,743354	SIO2	1,560491	83,5
47	180,351521	-1,580032			92,3
48	1793,077203	-23,224027	SIO2	1,560491	102,7
49	346,025735	-46,740042			107,1
50	-587,720308	-49,840882	SIO2	1,560491	138,2
51	362,715565	-0,996413			139,9
52	-802,776800	-32,541316	SIO2	1,560491	143,2
53	1200,879163	-20,610535			143,1
54	0,000000	19,614848			138,0
55	-277,707719	-52,291236	SIO2	1,560491	141,8
56	708,666176	-0,995494			139,7
57	-424,462858	-35,408449	SIO2	1,560491	134,6
58	920,517618	-0,994818			131,9
59	-257,650413	-33,302544	SIO2	1,560491	115,0
60	-3892,659133	-0,993481			109,3
61	-150,518437	-37,001664	SIO2	1,560491	91,7
62	-815,328045	-1,000000			83,2
63	-54,709895	-42,146539	SIO2	1,560491	49,5
64	0,000000	-3,000000	H2O	1,436822	24,8
65	0,000000	0,000000			18,4

Table 16A

ASPHERIC CONSTANTS

SRF	8	19	22	25	31
K	0	0	0	0	0
C1	9,477707E-08	-1,630325E-08	8,446555E-09	3,545371E-09	3,545371E-09
C2	1,961231E-12	-9,812446E-14	2,275492E-13	-6,774437E-13	-6,774437E-13
C3	-4,595943E-16	-1,945238E-18	-8,360514E-19	4,237596E-17	4,237596E-17
C4	2,712352E-19	2,190264E-22	1,164424E-21	-5,726376E-21	-5,726376E-21
C5	-3,717129E-23	-2,392299E-26	-6,873389E-26	1,719638E-25	1,719638E-25
C6	2,062145E-27	8,993812E-31	2,030241E-30	1,264086E-29	1,264086E-29

SRF	34	42	46	48	51
K	0	0	0	0	0
C1	8,446555E-09	-3,731377E-08	-7,541203E-09	3,402805E-08	-7,582220E-09
C2	2,275492E-13	-5,506103E-12	3,280912E-12	-2,111476E-12	-1,607342E-13
C3	-8,360514E-19	1,183283E-15	-1,338960E-16	3,392400E-17	-9,929315E-18
C4	1,164424E-21	-1,705010E-19	-2,204551E-20	-3,518123E-21	-4,709955E-22
C5	-6,873389E-26	1,532771E-23	5,087511E-26	1,006578E-24	4,064977E-26
C6	2,030241E-30	-6,241836E-28	-4,751065E-28	-2,276157E-29	-5,868799E-31

SRF	56	57	60
K	0	0	0
C1	-5,466505E-08	3,173474E-08	4,604026E-09
C2	1,620583E-12	-1,360966E-12	-4,261817E-12
C3	-3,331287E-17	4,744992E-17	3,289463E-16
C4	2,561164E-21	9,163771E-22	-2,280425E-20
C5	-1,070898E-25	-7,066436E-26	9,960289E-25
C6	1,395421E-30	7,159877E-31	-2,271390E-29

Table 17

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0	0,000000	35,062171			61,5
1	160,377892	33,915692	SIO2	1,560491	85,2
2	4339,545820	35,211752			85,0
3	134,501543	9,996831	SIO2	1,560491	83,7
4	111,692176	24,343835			80,0
5	176,022408	44,412851	SIO2	1,560491	81,0
6	-158,125766	1,097941			79,5
7	70,127955	63,281412	SIO2	1,560491	62,6
8	80,899024	23,149420			37,4
9	-104,439732	28,493683	SIO2	1,560491	39,7
10	-76,691544	9,373106			50,2
11	-66,201313	9,999364	SIO2	1,560491	51,9
12	-449,321456	12,356383			69,1
13	-193,830863	41,850652	SIO2	1,560491	73,7
14	-96,808240	0,997395			83,6
15	-309,193570	53,879882	SIO2	1,560491	100,4
16	-121,506051	0,996721			106,4
17	-1347,934891	32,667851	SIO2	1,560491	110,7
18	-232,958167	69,997839			112,2
19	0,000000	-95,009945	REFL		106,8
20	-169,601782	-49,964697	SIO2	1,560491	108,4
21	-2559,597028	-244,909101			104,7
22	94,645450	-12,500000	SIO2	1,560491	70,0
23	2366,726589	-50,185589			83,9
24	96,645650	-12,500000	SIO2	1,560491	86,5
25	158,153978	-11,143815			106,9
26	150,128583	11,143815	REFL		111,0
27	158,153978	12,500000	SIO2	1,560491	106,9
28	96,645650	50,185589			86,5
29	2366,726589	12,500000	SIO2	1,560491	83,9
30	94,645450	244,909101			70,0
31	-2559,597028	49,964697	SIO2	1,560491	104,7
32	-169,601782	95,009945			108,4
33	0,000000	-69,996314	REFL		106,9
34	-281,792007	-41,385881	SIO2	1,560491	110,8
35	657,889902	-0,997396			109,7
36	-174,312217	-32,438650	SIO2	1,560491	100,1
37	-476,477690	-1,935634			95,7
38	-123,498799	-34,625674	SIO2	1,560491	85,0
39	-152,214034	-29,454227			73,4
40	230,398053	-9,988522	SIO2	1,560491	71,5
41	-84,263230	-42,301978			62,8
42	148,358426	-9,995751	SIO2	1,560491	64,2
43	-285,965468	-29,500257			76,2
44	1365,214672	-52,201213	SIO2	1,560491	91,3
45	197,964169	-1,405485			110,1

46	471,452295	-43,072393	SIO2	1,560491	120,4
47	209,873148	-1,120291			130,5
48	-1186,156898	-60,630783	SIO2	1,560491	155,2
49	325,015642	-0,999174			157,9
50	-2211,880008	-27,251892	SIO2	1,560491	162,5
51	1353,381133	-0,997683			163,0
52	-333,578758	-60,245043	SIO2	1,560491	162,7
53	664,853013	-3,960500			160,4
54	0,000000	2,974292			153,2
55	-436,081909	-40,203050	SIO2	1,560491	152,1
56	1058,418471	-0,974875			149,3
57	-242,988440	-46,663567	SIO2	1,560491	127,0
58	1737,489827	-0,944194			120,7
59	-113,935104	-37,162408	SIO2	1,560491	86,5
60	-237,094762	-1,000000			75,1
61	-53,008742	-37,444181	SIO2	1,560491	48,1
62	0,000000	-3,000000	H2O	1,436823	26,7
63	0,000000	0,000000			18,4

Table 17A

ASPHERIC CONSTANTS

SRF	6	17	20	23	29
K	0	0	0	0	0
C1	1,567356E-07	-1,504554E-08	1,102741E-08	1,329977E-08	1,329977E-08
C2	-1,454311E-12	-1,033827E-13	3,161475E-13	-6,446967E-13	-6,446967E-13
C3	-4,821299E-16	-5,875858E-18	-3,234527E-18	2,574587E-17	2,574587E-17
C4	3,177351E-19	7,367131E-22	1,863348E-21	2,145483E-21	2,145483E-21
C5	-4,247779E-23	-5,690740E-26	-1,058278E-25	-6,859442E-25	-6,859442E-25
C6	2,417313E-27	1,690737E-30	3,288177E-30	4,363205E-29	4,363205E-29

SRF	32	40	44	46	49
K	0	0	0	0	0
C1	1,102741E-08	-7,623733E-08	5,961950E-08	4,163425E-08	1,556511E-08
C2	3,161475E-13	-2,696128E-12	2,260719E-12	-2,205874E-12	-9,513867E-13
C3	-3,234527E-18	1,720996E-15	1,675440E-17	-2,145810E-18	1,334037E-17
C4	1,863348E-21	-3,583626E-19	9,620913E-21	-9,265446E-21	-6,577842E-22
C5	-1,058278E-25	3,893269E-23	-4,439958E-24	1,471307E-24	4,785308E-26
C6	3,288177E-30	-1,781650E-27	-3,165933E-29	-4,599952E-29	-1,010940E-30

SRF	53	55	58
K	0	0	0
C1	-4,190276E-08	3,093715E-08	6,193974E-09
C2	1,643663E-12	-1,212659E-12	-3,507726E-12
C3	-4,727323E-17	4,234860E-17	2,841523E-16
C4	7,314393E-22	-1,652445E-21	-1,871154E-20
C5	7,386195E-27	5,642952E-26	7,577332E-25
C6	-2,389707E-31	-7,153949E-31	-1,502450E-29

Table 18

Tab.	D_{max}	D_M	D_M / D_{max}	Y'	NA	N_L	N_{OP}	COMP1	COMP2	COMP3
1	256.8	235.2	0.92	14.4	1.2	23	3	12.4	284.5	94.8
3	252.9	243.3	0.96	14.4	1.1	25	3	14.5	362.4	120.8
9	270.6	230.6	0.85	16.0	1.2	28	3	11.7	328.9	109.6
10	277.8	236.4	0.85	16.0	1.2	28	3	12.1	337.6	112.5
11	293.4	197.4	0.67	16.0	1.3	27	3	10.9	293.0	97.7
12	267.0	201.0	0.75	16.0	1.25	27	3	10.7	288.4	96.1
13	285.2	203.6	0.71	16.0	1.25	27	3	11.4	308.0	102.7
15	286.4	212.8	0.74	16.1	1.3	27	3	10.5	283.8	94.6
16	286.4	213.0	0.74	15.4	1.3	27	3	11.0	297.6	99.2
17	326.0	222.0	0.68	15.4	1.35	26	3	11.6	302.5	100.8

What is claimed is:

1. A catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging of an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and
- a third objective part for imaging the second real intermediate image on the image plane; wherein
- the second objective part is a catadioptric objective part with a concave mirror;
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided; and
- a field lens with a positive refractive power is arranged between the first intermediate image and the concave mirror, in a region close to the field of the first intermediate image.

2. The projection objective as claimed in claim 1, wherein the field lens is arranged in the optical vicinity of at least one intermediate image in a region in which the chief ray height of the image is large in comparison to the marginal ray height.

3. The projection objective as claimed in claim 1, wherein the field lens is a single lens.

4. The projection objective as claimed in claim 1,

wherein the field lens is arranged closer to the first folding mirror than to the concave mirror.

5. The projection objective as claimed in claim 1, wherein the concave mirror has an associated folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror, or deflecting the radiation coming from the concave mirror in the direction of the image plane, and a field lens with positive refractive power is arranged geometrically between the concave mirror and the folding mirror in a region through which the beam passes twice, in such a manner that a first lens area of the field lens is arranged in the beam path between the object plane and the concave mirror, and a second lens area of the field lens is arranged in the beam path between the concave mirror and the image plane.

6. The projection objective as claimed in claim 1, wherein the field lens is arranged such that it is arranged not only in the optical vicinity of the first intermediate image, which is located in the beam path upstream from the concave mirror, but also in the optical vicinity of the second intermediate image, which is located in the beam path downstream from the concave mirror.

7. The projection objective as claimed in claim 1, wherein the field lens is arranged in a region through which the beam passes twice and has a first lens area, through which the beam passes in a first direction, and a second lens area, through which the beam passes in a second direction, with the first lens area and the second lens area not overlapping one another, at least on one side of the lens.

8. The projection objective as claimed in claim 1, wherein the projection objective has an image-side numerical aperture of NA > 0.85, and an image-side working distance of $A \leq 10$ mm.

9. The projection objective as claimed in claim 8, wherein the image-side working distance is between about 1 mm and about 8 mm.

10. The projection objective as claimed in claim 1, which is in the form of an immersion objective such that an immersion medium with a high refractive index is introduced between an exit surface of the projection objective and an incoupling surface of the substrate during operation.

11. The projection objective as claimed in claim 10, wherein the immersion medium has a refractive index of $n_I \geq 1.3$ at an operating wavelength of the projection objective.

12. The projection objective as claimed in claim 10, which has an image-side numerical aperture of $NA > 1$ in conjunction with the immersion medium.

13. The projection objective as claimed in claim 12, wherein the numerical aperture is $NA \geq 1$, and/or $NA \geq 1.1$, and/or $NA \geq 1.2$.

14. The projection objective as claimed in claim 1, which has two, and only two, real intermediate images.

15. The projection objective as claimed in claim 1, wherein all of the intermediate images are arranged in the vicinity of a folding mirror.

16. The projection objective as claimed in claim 1, wherein all of the intermediate images are arranged at a distance from a folding mirror.

17. The projection objective as claimed in claim 1, wherein the third objective part is refractive.

18. The projection objective as claimed in claim 17, wherein the third objective part has a first lens group which follows the second intermediate

image and has a positive refractive power, a second lens group, which immediately follows the first lens group and has a negative refractive power, a third lens group which immediately follows the second lens group and has a positive refractive power, a fourth lens group which immediately follows the third lens group and has a positive refractive power, and a system diaphragm which is arranged in a transitional region from the third lens group to the fourth lens group.

19. The projection objective as claimed in claim 18, wherein the third lens group has an entry surface which is located in the vicinity of a point of inflection of a marginal ray height between the second lens group and the third lens group, with no negative lens with any substantial refractive power being arranged between this entry surface and the system diaphragm.

20. The projection objective as claimed in claim 19, wherein only positive lenses are arranged between the entry surface and the image plane.

21. The projection objective as claimed in claim 1, wherein a last optical element of the projection objective immediately upstream of the image plane is a plano-convex lens composed of calcium fluoride with a curved entry surface and an essentially planar exit suface.

22. The projection objective as claimed in claim 1, wherein at least one folding mirror is provided in the first objective part, such that the optical axis is folded at least once within the first objective part.

23. The projection objective as claimed in claim 1, wherein a folding mirror is arranged within at least one of the objective parts in such a manner that a field lens is arranged between the folding mirror and an intermediate image which is located closest to the folding mirror.

24. The projection objective as claimed in claim 1, wherein two of the objective parts are catadioptric, and each contains one concave mirror.

25. The projection objective as claimed in claim 1, wherein the first objective part is a catadioptric objective part with a concave mirror and an associated folding mirror, which is used as the first folding mirror.

26. The projection objective as claimed in claim 1, wherein the first objective part is a catadioptric objective part with a concave mirror and a physical beam splitter, which has a polarization-selective beam splitter surface, which is used as a folding mirror and separates the radiation that passes to the concave mirror of the first objective part from the radiation that is reflected from this concave mirror.

27. The projection objective as claimed in claim 1, wherein the folding mirrors are arranged in such a manner that a first beam section which runs from the object plane to the concave mirror and a second beam section which runs from the concave mirror to the image plane is generated, and one folding mirror is arranged with respect to the concave mirror in such a manner that one of the beam sections is folded on the folding mirror and the other beam section passes the folding mirror without any vignetting, and the first beam section and the second beam section cross over in a crossing area.

28. The projection objective as claimed in claim 27, wherein the first folding mirror is arranged such that the first beam section is folded on the first folding mirror, and the second beam section passes the first folding mirror without any vignetting.

29. The projection objective as claimed in claim 1, which has a catadioptric objective part which has a concave mirror and a first folding mirror, which is associated with the concave mirror, for deflecting the radiation coming from the object plane to the concave mirror,
wherein a second folding mirror is provided for deflecting the radiation reflected from the concave mirror to the image plane, and the second folding

mirror is at least partially located in an axial region which is located between the object plane and the first folding mirror in the direction of the optical axis.

30. The projection objective as claimed in claim 1, wherein the first folding mirror has an inner mirror edge which is close to the optical axis, and an intermediate image is arranged in the geometric vicinity of the inner mirror edge.

31. The projection objective as claimed in claim 1, which is designed for ultraviolet light from a wavelength range between about 120 nm and about 260 nm.

32. A projection exposure system for microlithography having an illumination system and a catadioptric projection objective for imaging of a pattern, which is arranged on an object plane of the projection objective, on an image plane of the projection objective, having:
a first objective part for imaging an object field to form a first real intermediate image,
a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and
a third objective part for imaging of the second real intermediate image on the image plane; wherein
the projection objective is designed as claimed in Claim 1.

33. A method for producting semiconductor components and other finely structured components, comprising the following steps:
Providing a mask with a predetermined pattern in the region of an object plane of a catadioptric projection objective;
Illuminating the mask with ultraviolet light at a predetermined wavelength;
Projecting an image of the pattern onto a light-sensitive substrate, which is arranged in the region of the image plane of a projection objective, with the aid of a catadioptric projection objective as claimed in Claim 1.

34. A method for producing semiconductor components and other finely structured components, comprising the following steps:
Providing a mask with a predetermined pattern in a region of an object plane of a catadioptric projection objective;
Illuminating of the mask with ultraviolet light at a predetermined wavelength;
Projecting an image of the pattern onto a light-sensitive substrate, which is arranged in the region of the image plane of a projection objective, with the aid of a catadioptric projection objective as claimed in Claim 1;
wherein, during projecting, the beam passes through an immersion medium which is arranged between a last optical surface of the projection objective and the substrate.

35. A catadioptric projection objective for imaging a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and
- a third objective part for imaging the second real intermediate image on the image plane; wherein
- the second objective part is a catadioptric objective part with a concave mirror;
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided; and
- wherein the projection objective has an image-side numerical aperture of NA > 0.85, and a field lens with a positive refractive power is arranged between the first intermediate image and the concave mirror, in a region close to the field of the first intermediate image.

36. A catadioptric projection objective for imaging a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and
- a third objective part for imaging the second real intermediate image on the image plane; wherein
- the second objective part is a catadioptric objective part with a concave mirror;
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided;
- wherein the first and the second folding mirror are arranged in such a manner that a first beam section which runs from the object plane to the concave mirror and a second beam section which runs from the concave mirror to the image plane is generated, and one folding mirror is arranged with respect to the concave mirror in such a manner that one of the beam sections is folded on the folding mirror, and the other beam section passes the folding mirror without any vignetting, and the first beam section and the second beam section cross over in a crossing area.

37. The projection objective as claimed in claim 36, which has an image-side numerical aperture of NA > 0.85.

38. The projection objective as claimed in claim 36, wherein a field lens with a positive refractive power is arranged between the first intermediate image and the concave mirror in a region close to the field of the first intermediate image.

39. The projection objective according to claim 1, wherein a lateral axis offset AO is defined between a first part of the optical axis defined by the first objective part and a second part of the optical axis defined by the second objective part and aligned parallel to the first part of the optical axis,
an object-image-shift (OIS) is defined between an object field center and an image field center,
a finite object center height h is defined as a lateral distance between the object field center of an effective object field and the first part of the optical axis,
the projection objective has a magnification ratio β,
and wherein the following condition holds:

$$0 \leq OIS \leq |h \cdot (1+|\beta|)|.$$

40. The projection objective according to claim 39, wherein the condition OIS = 0 holds.

41. The projection objective according to claim 1, wherein a refractive power and a position of the field lens is set such that for a first chief ray direction cosine CRA1 at the first intermediate image the following relation holds:

$$|CRA1| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$

where β_1 denotes the magnification of the first objective part, Y_{OB} is the object height of the outermost field point for which the chief ray is considered and L_{HOA} is the geometrical distance from the first intermediate image to the concave mirror (length of the horizontal axis).

42. The projection objective according to claim 1, wherein a first chief ray direction cosine CRA1 at the first intermediate image and a second chief ray direction cosine CRA2 at a second intermediate image is defined and wherein the following conditions are fulfilled:

$$|CRA1| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$
$$|CRA2| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$

43. The projection objective according to claim 1, wherein a first axial length AL1 of the first objective part is smaller than a third axial length AL3 of the third objective part, wherein the axial length AL1 is measured between the object plane and an intersection of the optical axis with the first folding mirror and the axial length AL3 is measured between the intersection of the optical axis with the second folding mirror and the image plane.

44. The projection objective according to claim 43, wherein the condition AL1/AL3 < 0,9 holds.

45. The projection objective according to claim 1, wherein an intermediate image is extended axially in an intermediate image space defined between a position of a paraxial intermediate image and an axial position of a marginal ray intermediate image and where no optical surface is positioned within the intermediate image space.

46. The projection objective for imaging a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

a first refractive imaging objective part and at least one second refractive imaging objective part,

where at least one lens is arranged optically within both the first and the second imaging objective part.

47. A catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging of an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and
- a third objective part for imaging the second real intermediate image on the image plane; wherein
- the second objective part is a catadioptric objective part with a concave mirror;
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror or for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided; and
- a field lens with a positive refractive power is arranged geometrically between the first folding mirror and the concave mirror, in a region close to the field of the first intermediate image.

48. The projection objective as claimed in claim 47, wherein the field lens is arranged geometrically between the concave mirror and the first folding mirror in a region through which the beam passes twice, in such a manner that a first lens area of the field lens is arranged in the beam path between the object plane and the concave mirror, and a second lens area of the field lens is arranged in the beam path between the concave mirror and the image plane.

49. The projection objective according to claim 47, wherein a lateral axis offset AO is defined between a first part of the optical axis defined by the first objective part and a second part of the optical axis defined by the second objective part and aligned parallel to the first part of the optical axis,

an object-image-shift (OIS) is defined between an object field center and an image field center,
a finite object center height h is defined as a lateral distance between the object field center of an effective object field and the first part of the optical axis,
the projection objective has a magnification ratio β,
and wherein the following condition holds:

$$0 \leq OIS \leq |h \cdot (1+|\beta|)|.$$

50. The projection objective according to claim 47, wherein a refractive power and a position of the field lens is set such that for a first chief ray direction cosine CRA1 at the first intermediate image the following relation holds:

$$|CRA1| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$

where β_1 denotes the magnification of the first objective part, Y_{OB} is the object height of the outermost field point for which the chief ray is considered and L_{HOA} is the geometrical distance from the first intermediate image to the concave mirror (length of the horizontal axis).

51. The projection objective according to claim 47, wherein the projection objective has a maximum lens diameter D_{max}, a maximum image field height Y', an image side numerical aperture NA, a number N_L of lenses and a number N_{OP} of imaging objective parts concatenated at intermediate images; wherein
$COMP1 = D_{max} / (Y' \cdot NA^2)$
$COMP2 = D_{max} \cdot N_L / (Y' \cdot NA^2)$
$COMP3 = D_{max} \cdot N_L / (N_{OP} \cdot Y' \cdot NA^2)$;
and wherein at least one of the following conditions is fulfilled:
(1) $COMP1 < 11$

(2) COMP2 < 340

(3) COMP3 < 110

52. The projection objective according to claim 51, wherein COMP1 < 11 and COMP2 < 340.

53. The projection objective according to claim 47, wherein the concave mirror has a mirror diameter D_M, the projection objective has a maximum lens diameter D_{max}, and the condition $D_M < 0,75 * D_{max}$ holds.

54. The projection objective according to claim 47, wherein the projection objective has a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror and a second folding mirror for deflecting the radiation coming from the concave mirror in the direction of the image plane.

55. A catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging of an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part, the second objective part being a catadioptric objective part with a concave mirror; and
- a third objective part for imaging the second real intermediate image on the image plane; and
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror or for deflecting the radiation coming from the concave mirror in the direction of the image plane;

wherein a lateral axis offset AO is defined between a first part of the optical axis defined by the first objective part and a second part of the optical axis defined by the second objective part and aligned parallel to the first part of the optical axis,
an object-image-shift (OIS) is defined between an object field center and an image field center,
a finite object center height h is defined as a lateral distance between the object field center of an effective object field and the first part of the optical axis,
the projection objective has a magnification ratio β,
and wherein the following condition holds:

$$0 \leq OIS \leq |h \cdot (1+|\beta|)|.$$

56. The projection objective according to claim 55, wherein a refractive power and a position of the field lens is set such that for a first chief ray direction cosine CRA1 at the first intermediate image the following relation holds:

$$|CRA1| < |\beta_1 * (Y_{OB})/(L_{HOA})|$$

where β_1 denotes the magnification of the first objective part, Y_{OB} is the object height of the outermost field point for which the chief ray is considered and L_{HOA} is the geometrical distance from the first intermediate image to the concave mirror (length of the horizontal axis).

57. The projection objective as claimed in claim 55, which has an image-side numerical aperture of NA > 1 in conjunction with an immersion medium.

58. The projection objective as claimed in claim 57, wherein the numerical aperture is NA ≥ 1,3.

59. The projection objective as claimed in claim 55, wherein a field lens having positive refractive power is arranged geometrically between the concave mirror and the folding mirrors in a region through which the beam passes twice, in such a manner that a first lens area of the field lens is arranged in the beam path between the object plane and the concave mirror, and a second lens area of the field lens is arranged in the beam path between the concave mirror and the image plane.

60. The projection objective as claimed in claim 55, wherein the projection objective has a maximum lens diameter D_{max}, a maximum image field height Y', an image side numerical aperture NA, a number N_L of lenses and a number N_{OP} of imaging objective parts concatenated at intermediate images; wherein

$$COMP1 = D_{max} / (Y' \cdot NA^2)$$

$$COMP2 = D_{max} \cdot N_L / (Y' \cdot NA^2)$$

$$COMP3 = D_{max} \cdot N_L / (N_{OP} \cdot Y' \cdot NA^2) ;$$

and wherein at least one of the following conditions is fulfilled:

$$COMP1 < 11$$

$$COMP2 < 340$$

$$COMP3 < 110$$

61. The projection objective according to claim 60, wherein $COMP1 < 11$ and $COMP2 < 340$.

62. A catadioptric projection objective for imaging of a pattern, which is arranged on the object plane of the projection objective, on the image plane of the projection objective, having:

- a first objective part for imaging of an object field to form a first real intermediate image,
- a second objective part for generating a second real intermediate image using the radiation coming from the first objective part; and

- a third objective part for imaging the second real intermediate image on the image plane; wherein
- the second objective part is a catadioptric objective part with a concave mirror; and
- a first folding mirror for deflecting the radiation coming from the object plane in the direction of the concave mirror or for deflecting the radiation coming from the concave mirror in the direction of the image plane are provided;

wherein the projection objective has a maximum lens diameter D_{max}, a maximum image field height Y', an image side numerical aperture NA, a number N_L of lenses and a number N_{OP} of imaging objective parts concatenated at intermediate images; wherein

$COMP1 = D_{max} / (Y' \cdot NA^2)$

$COMP2 = D_{max} \cdot N_L / (Y' \cdot NA^2)$

$COMP3 = D_{max} \cdot N_L / (N_{OP} \cdot Y' \cdot NA^2)$;

and wherein at least one of the following conditions is fulfilled:

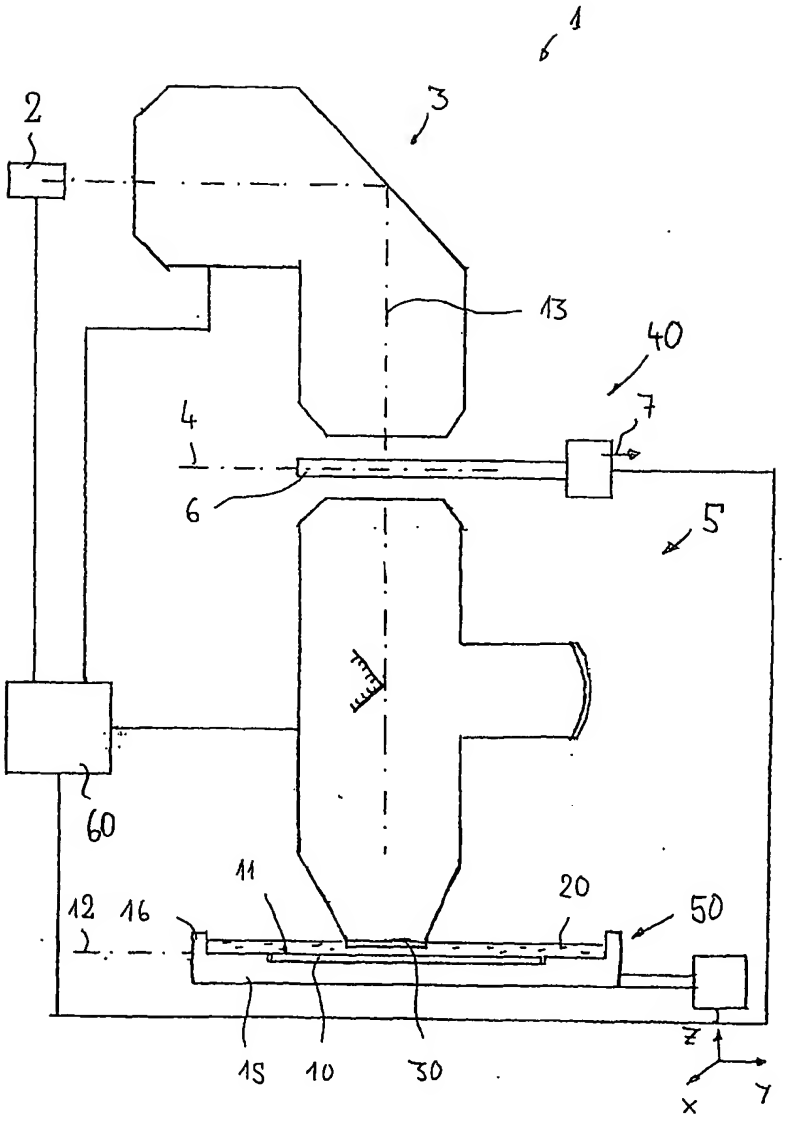
$COMP1 < 11$

$COMP2 < 340$

$COMP3 < 110$

63. The projection objective according to claim 60, wherein $COMP1 < 11$ and $COMP2 < 340$.

Fig 1



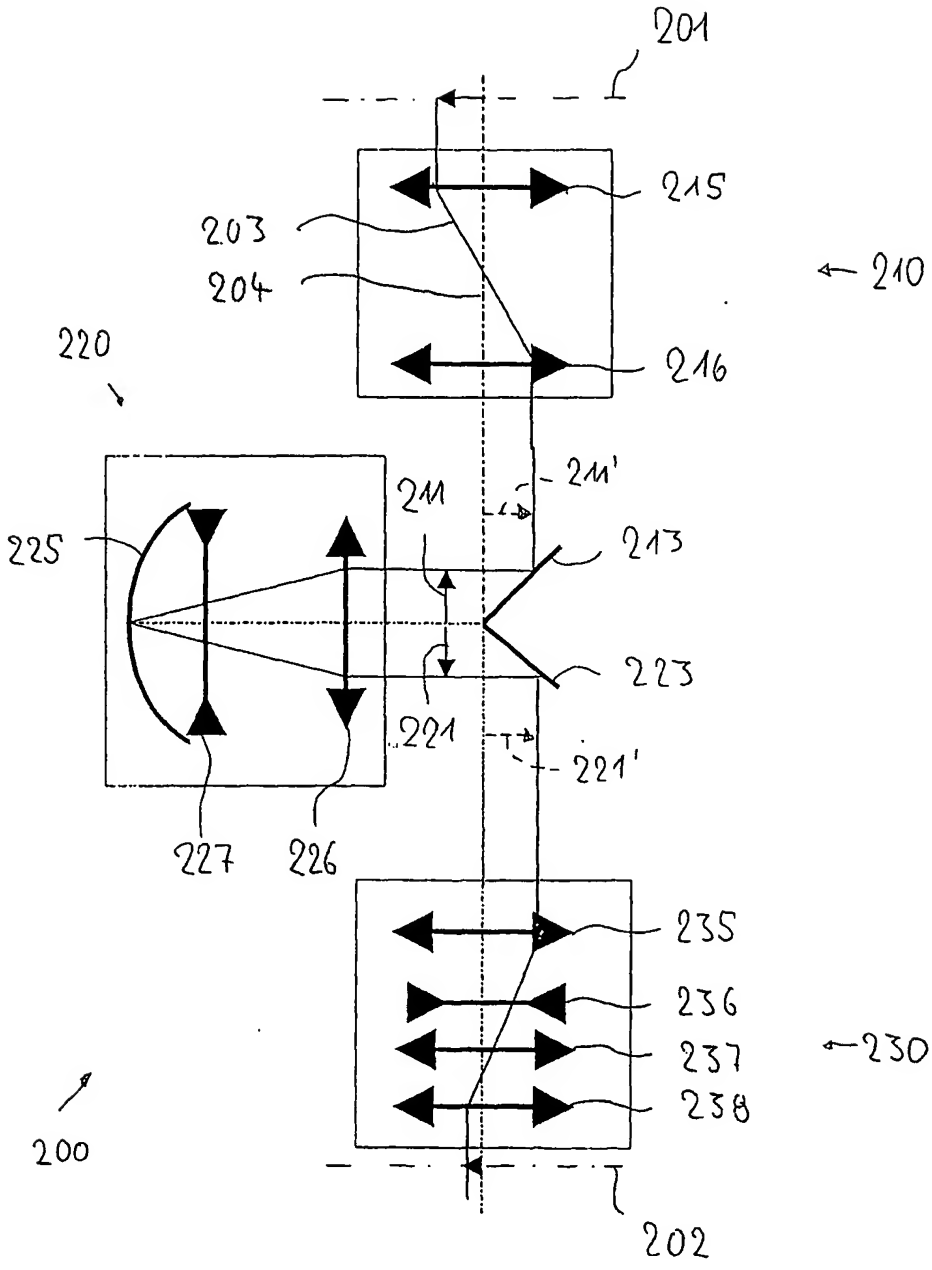

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Fig. 2

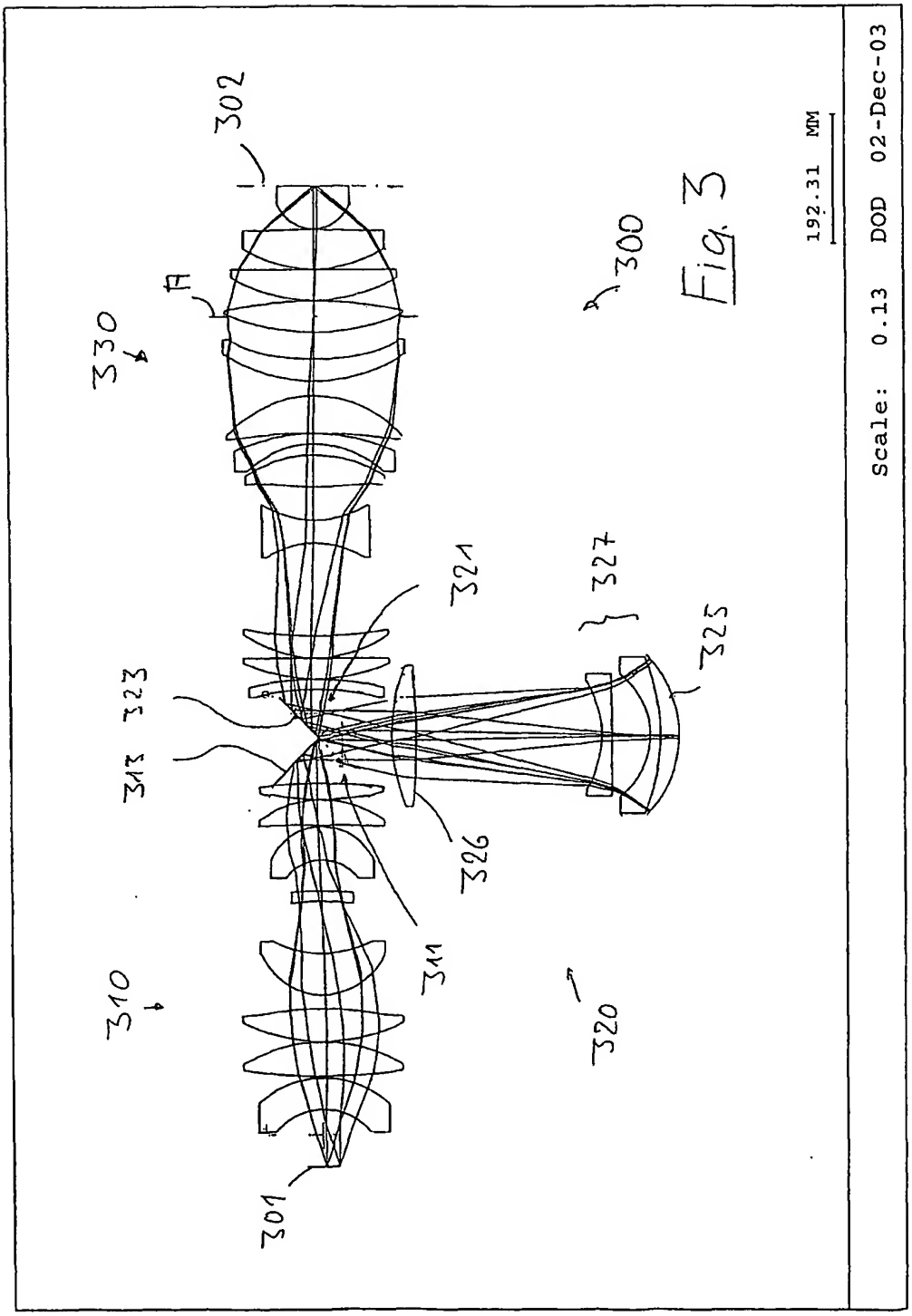
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Fig. 3

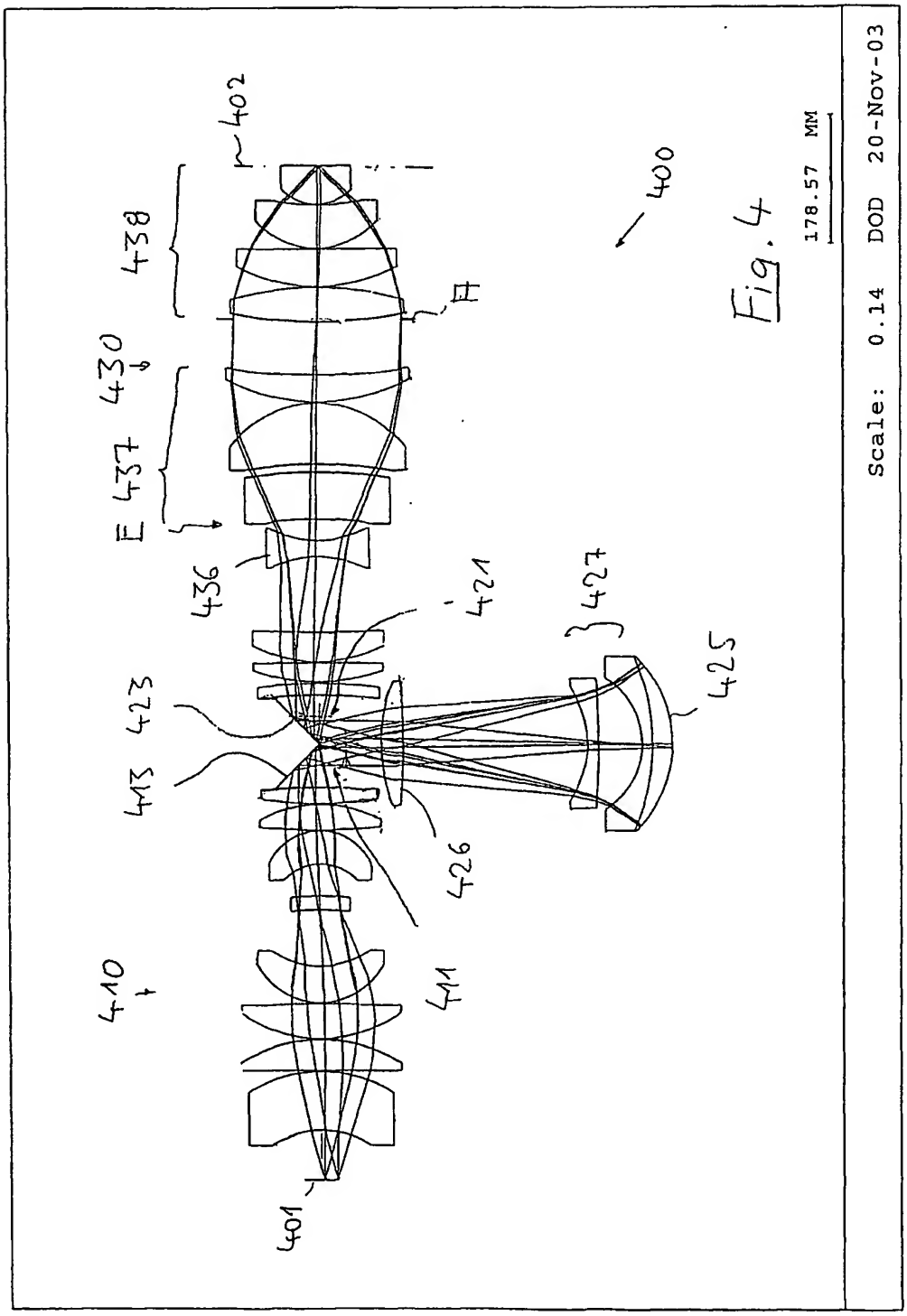
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Fig. 4

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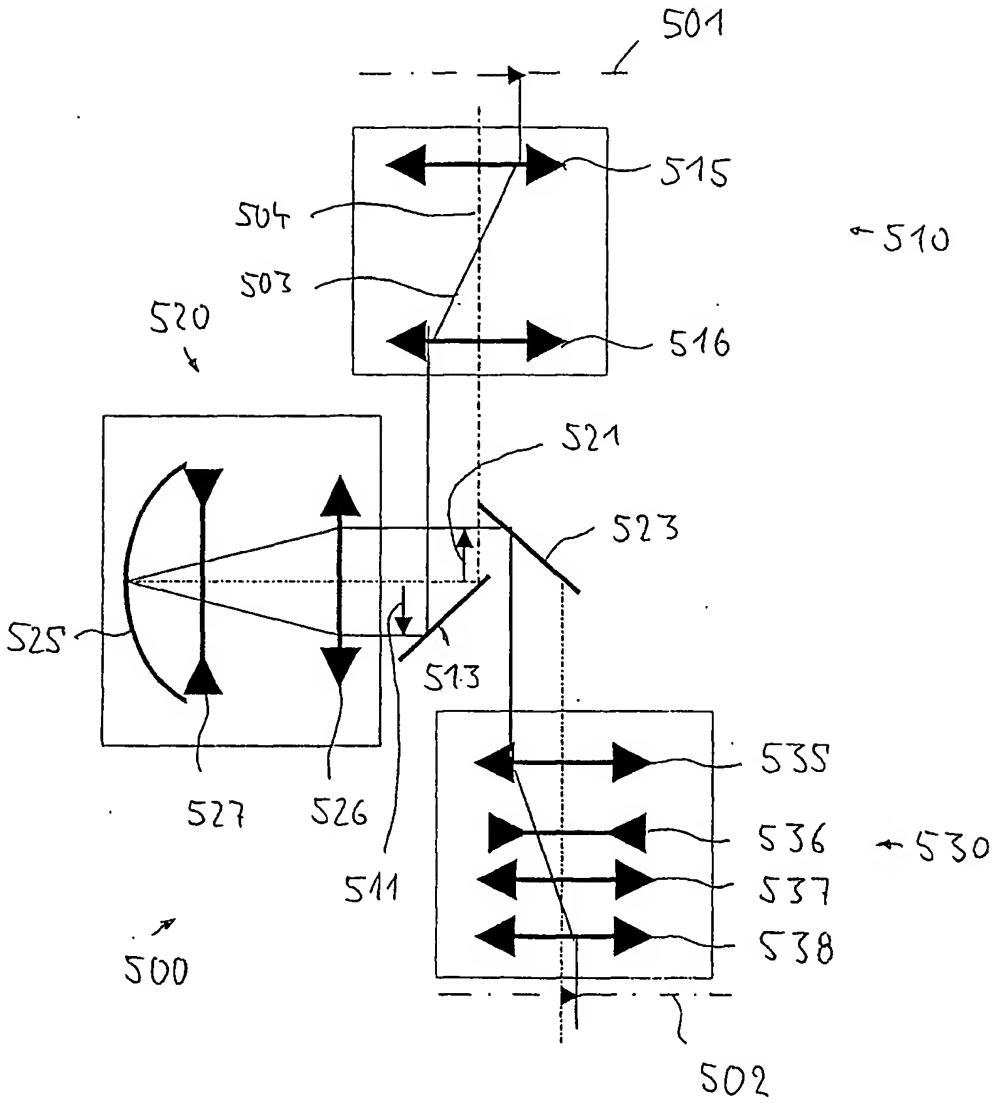
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Fig. 5

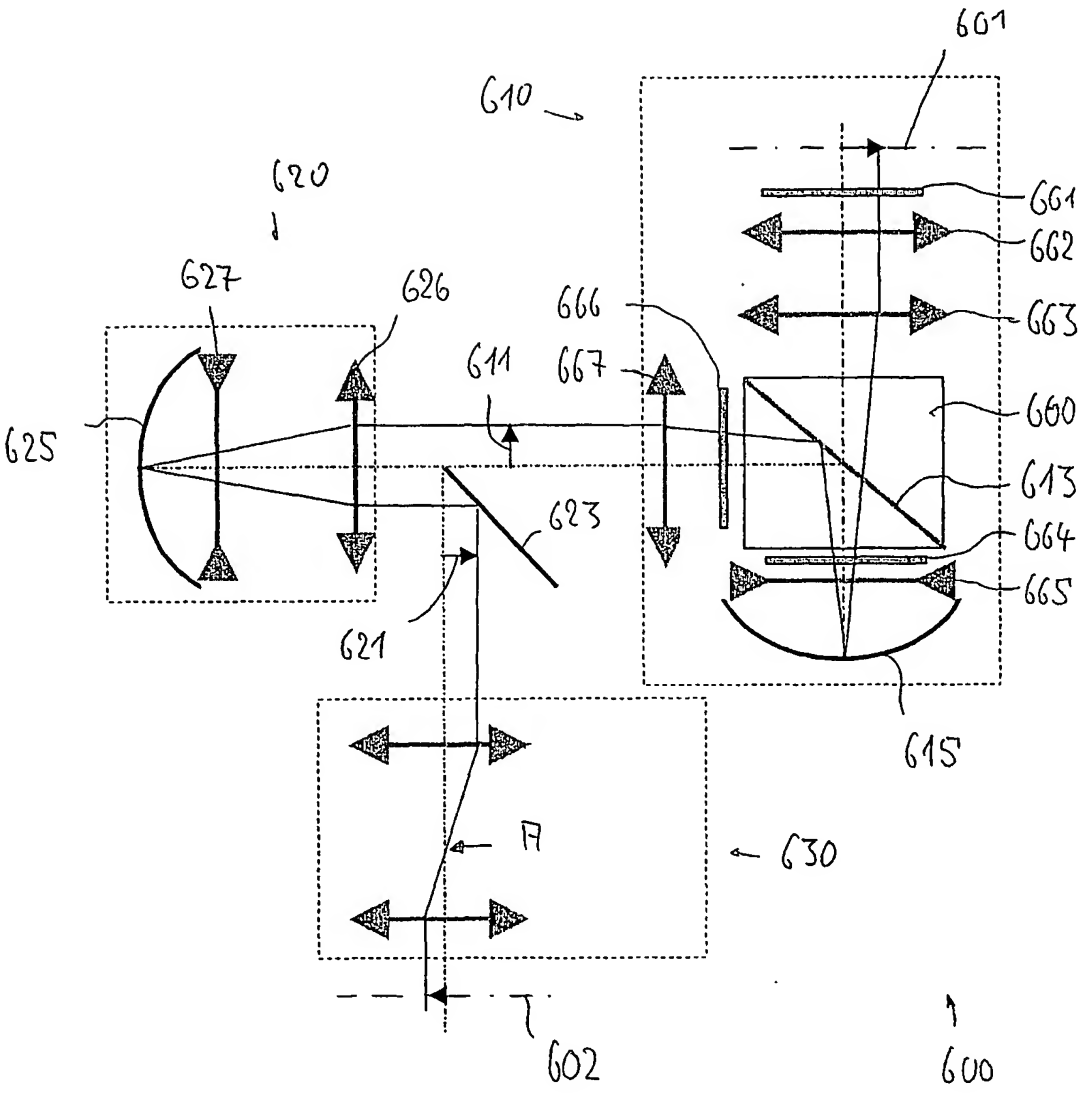
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Fig. 6

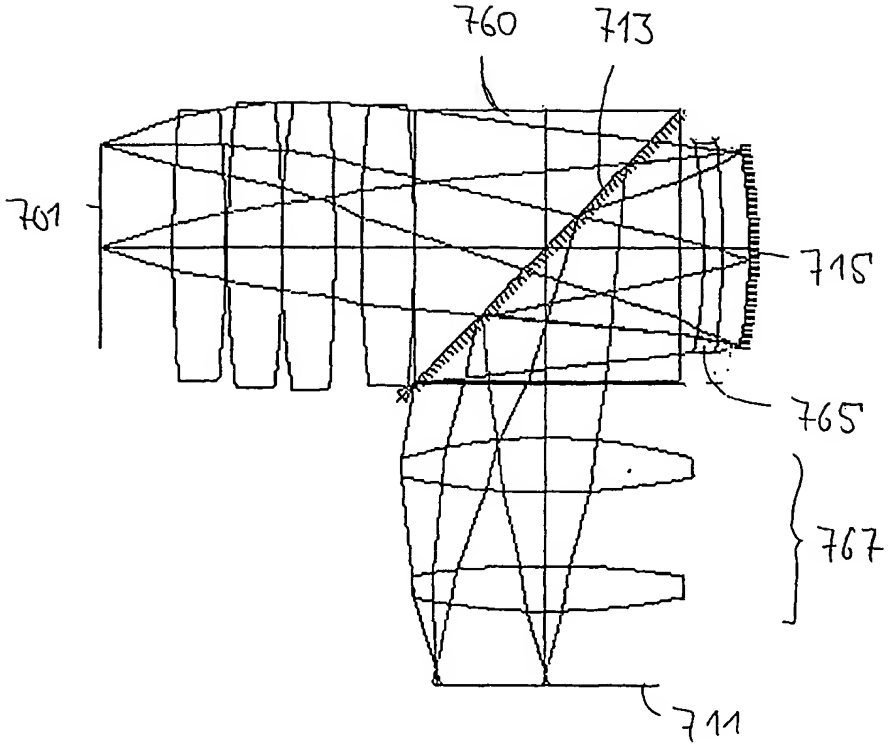

Fig. 7

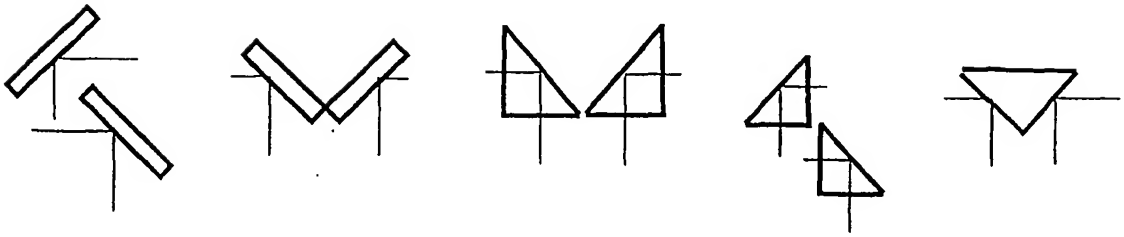

Fig. 8

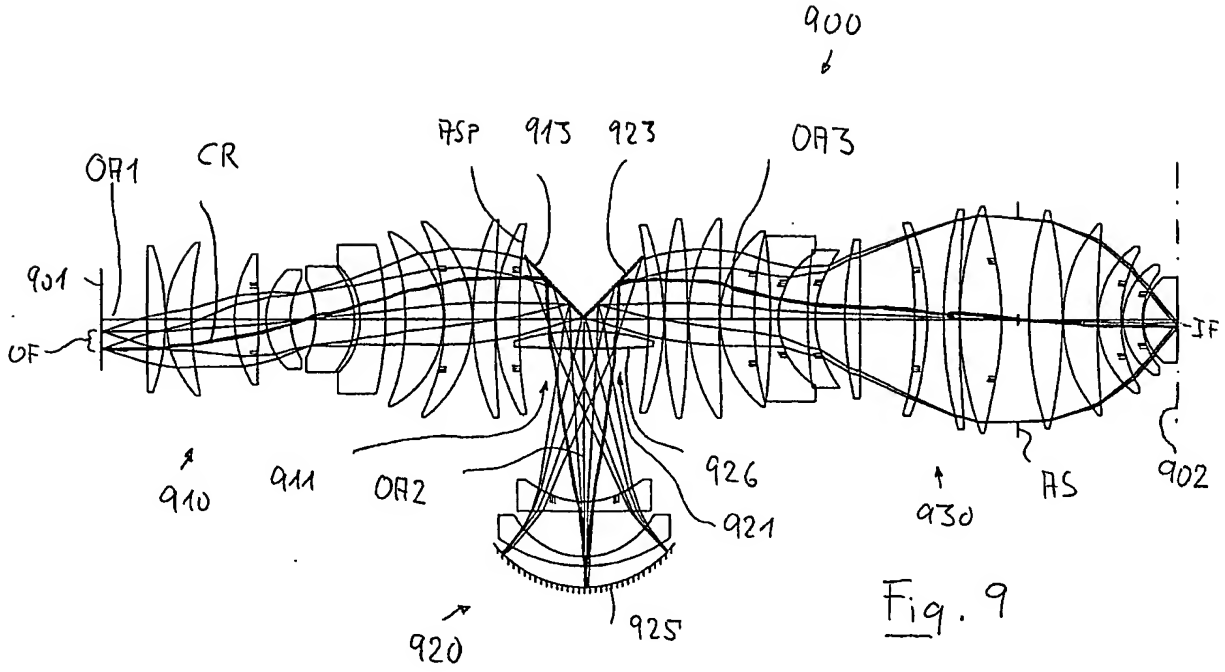
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Fig. 9

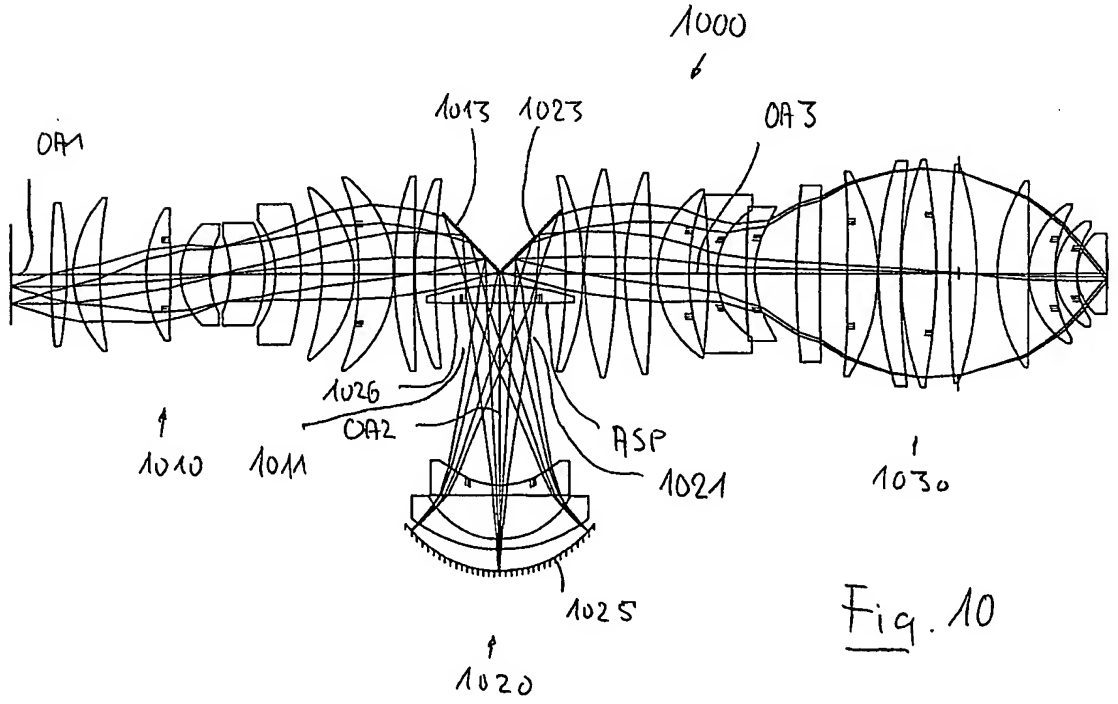
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Fig. 10

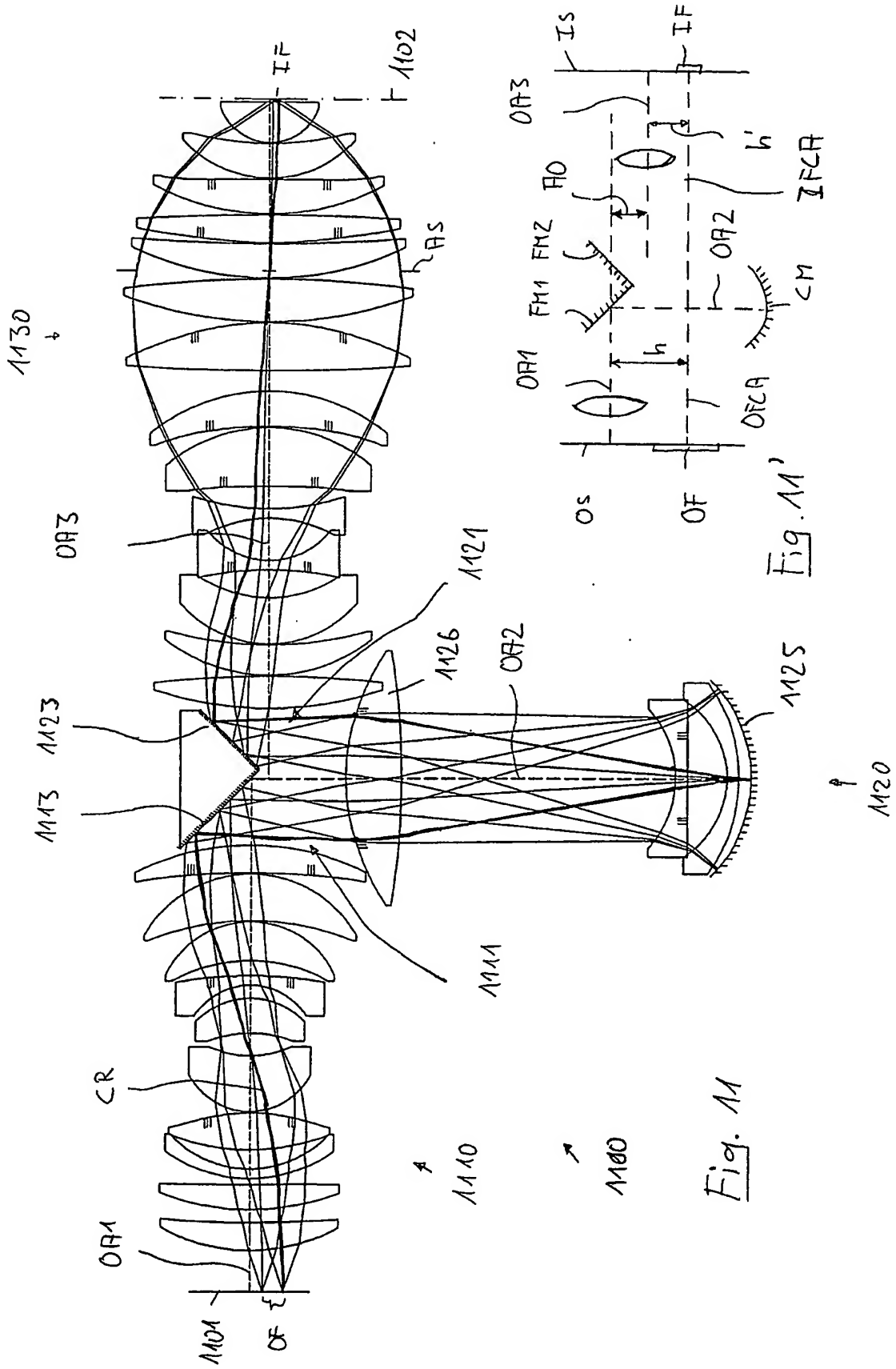
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Fig. 11

Fig. 11'

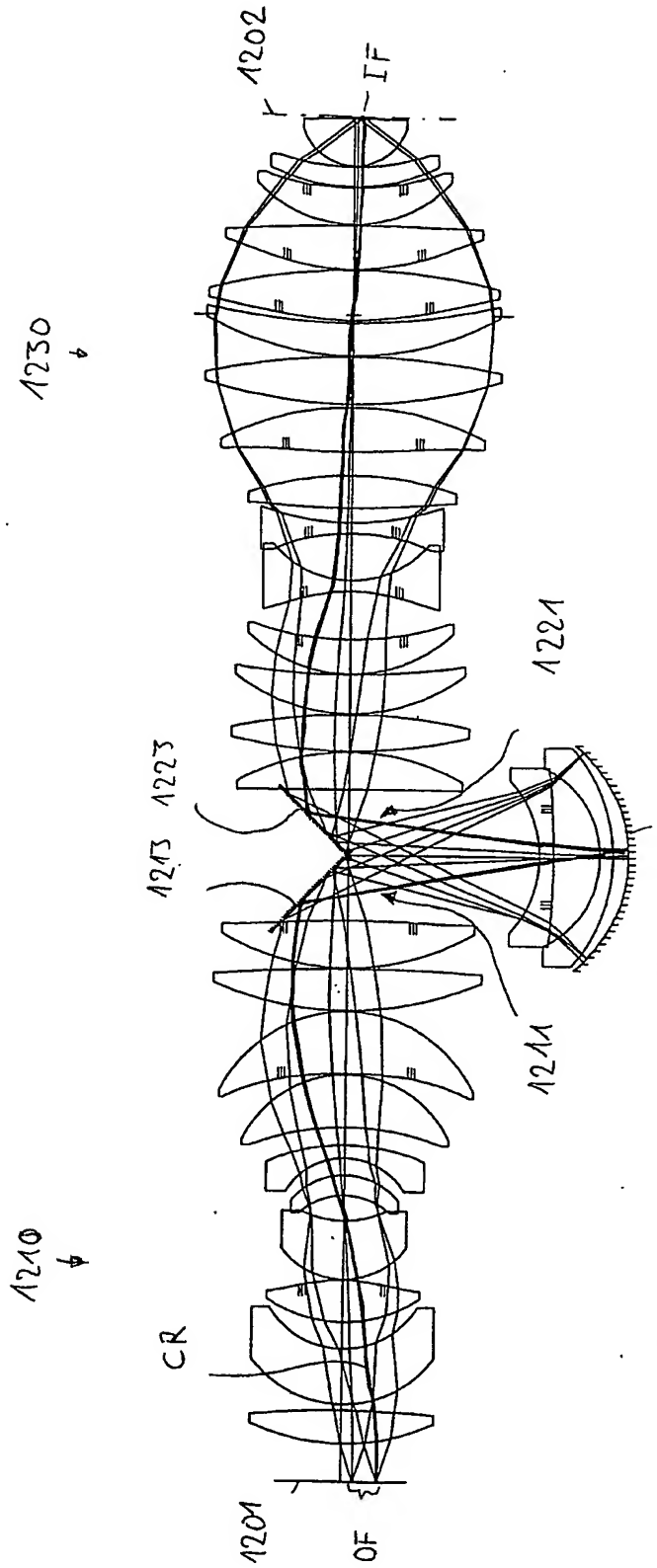
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Fig. 12

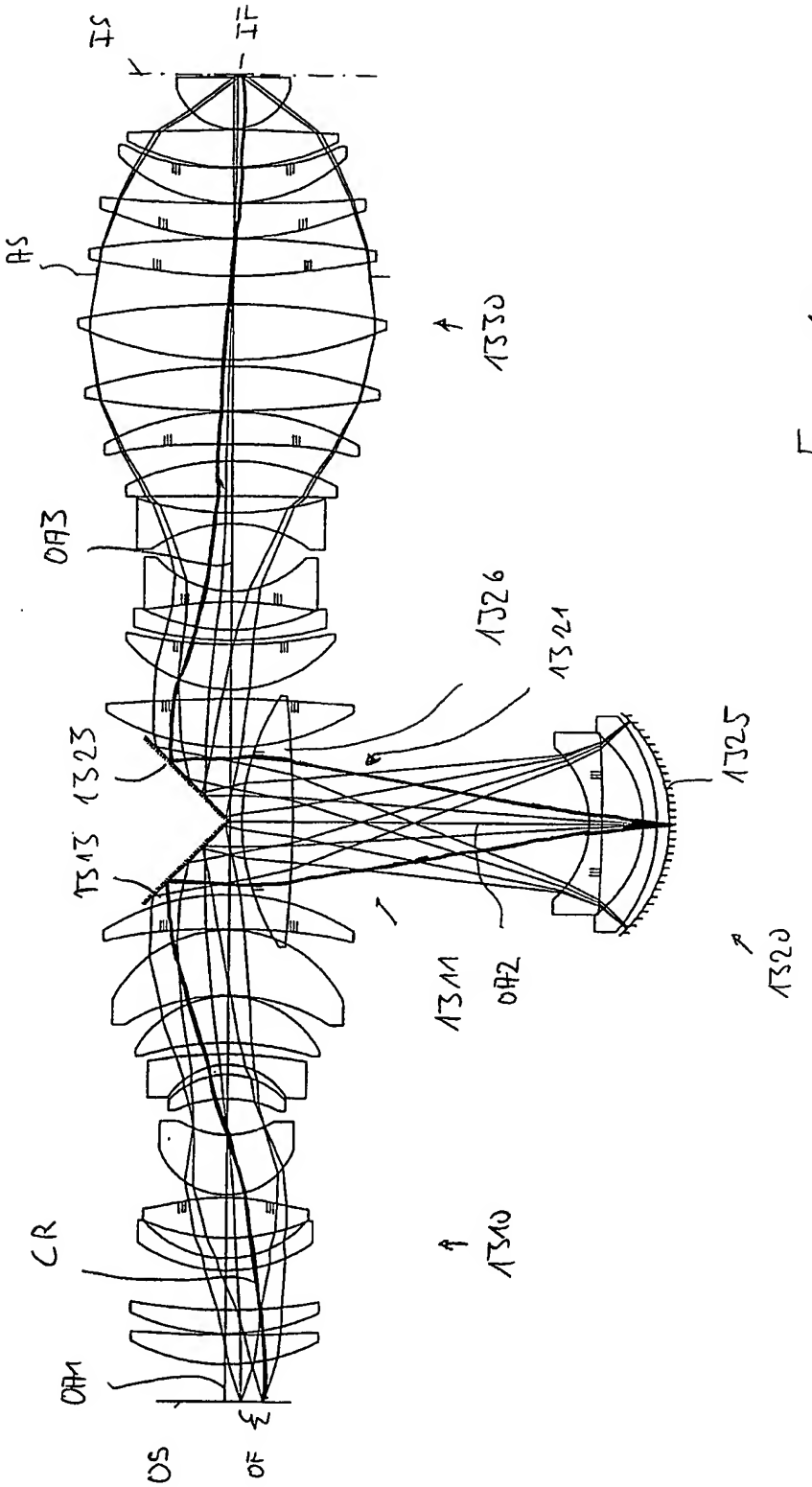
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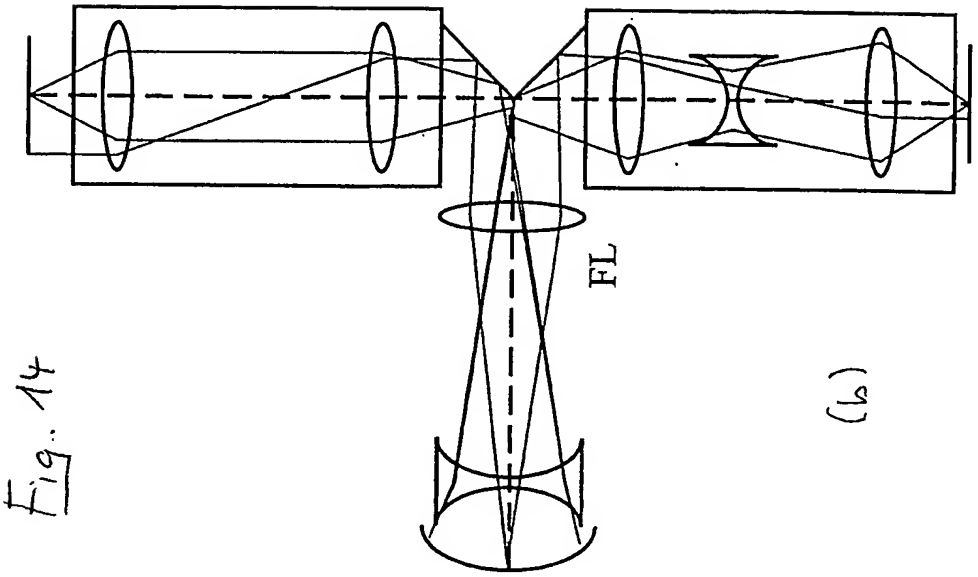
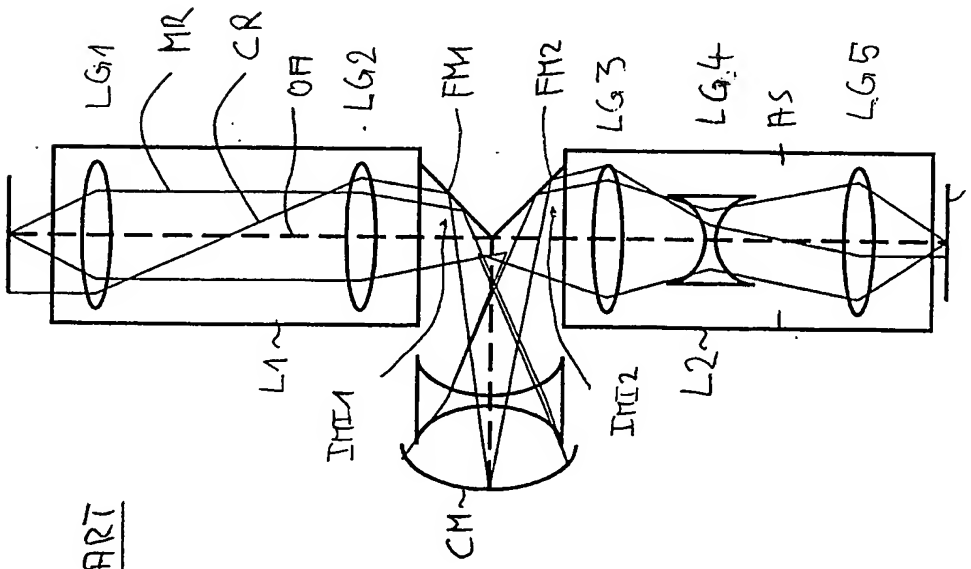
Fig. 13

Fig. 14



(b)



PRIOR ART

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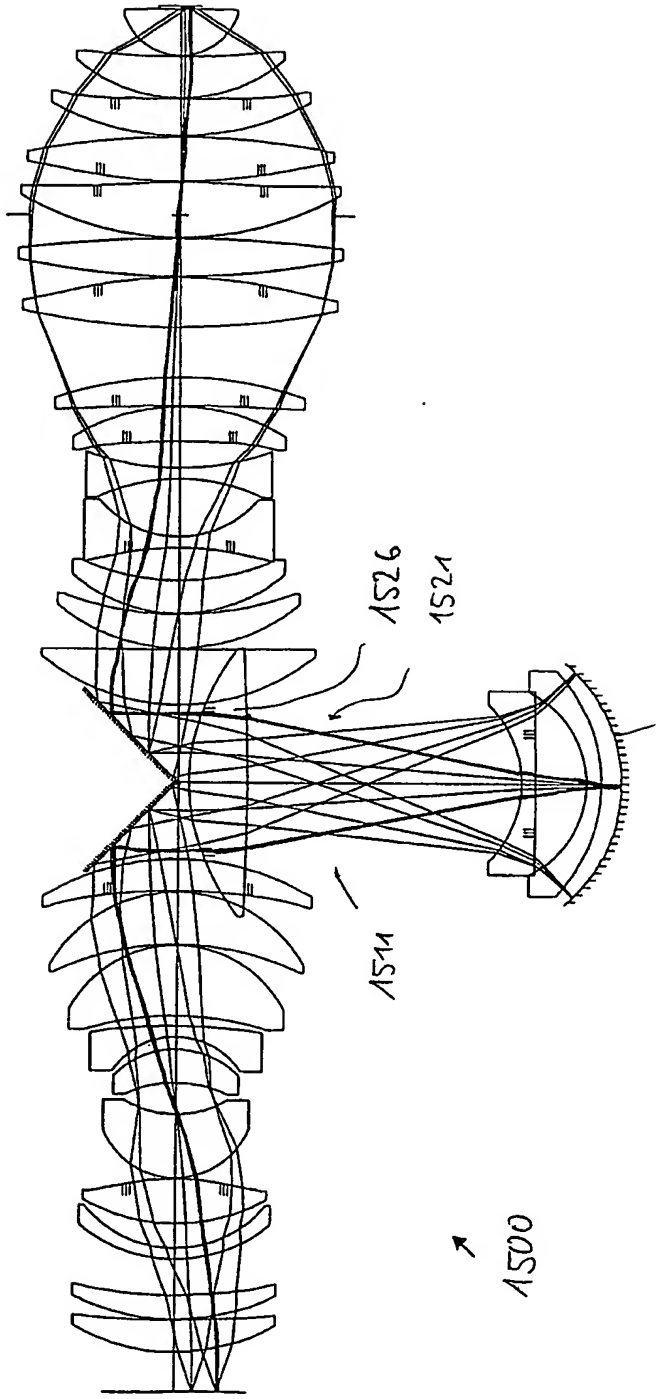

Fig. 15

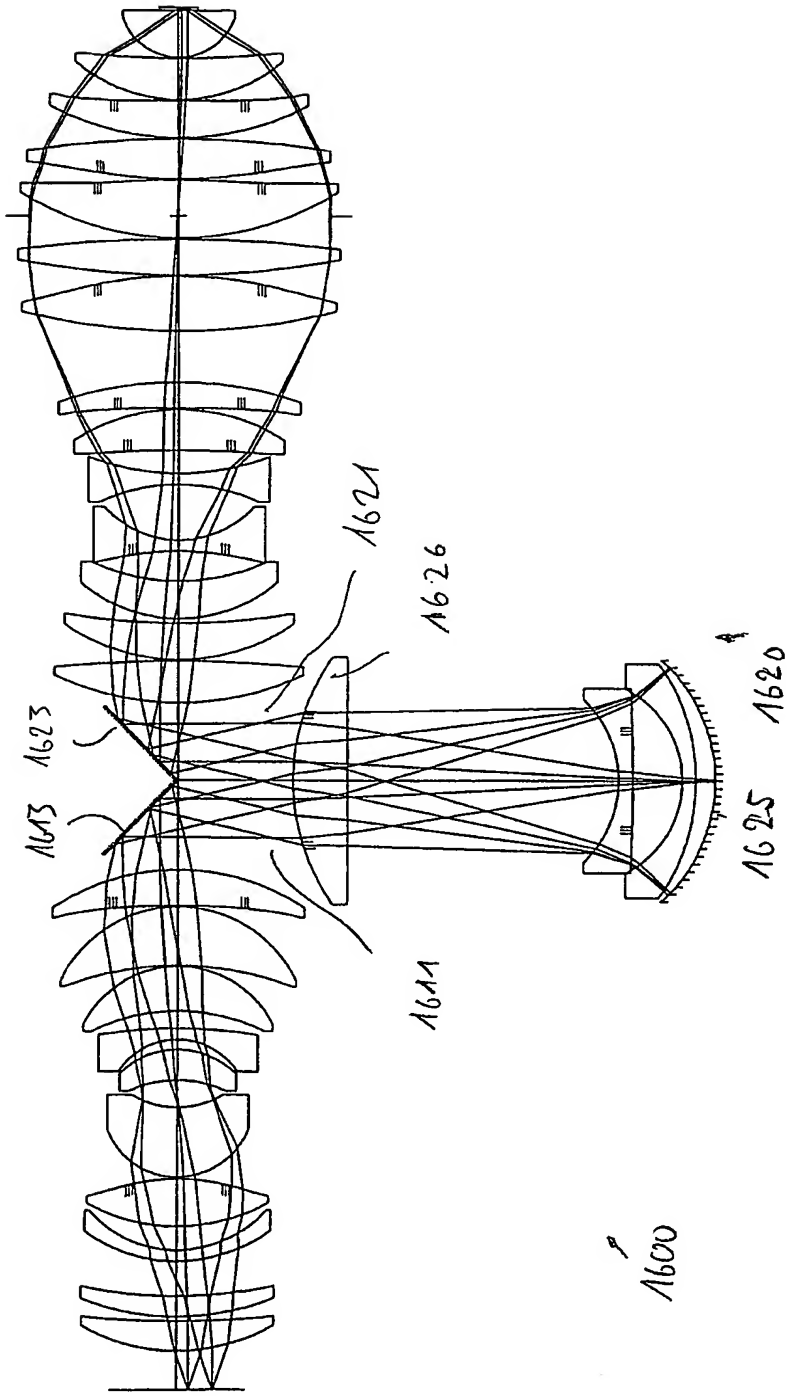

Fig. 16

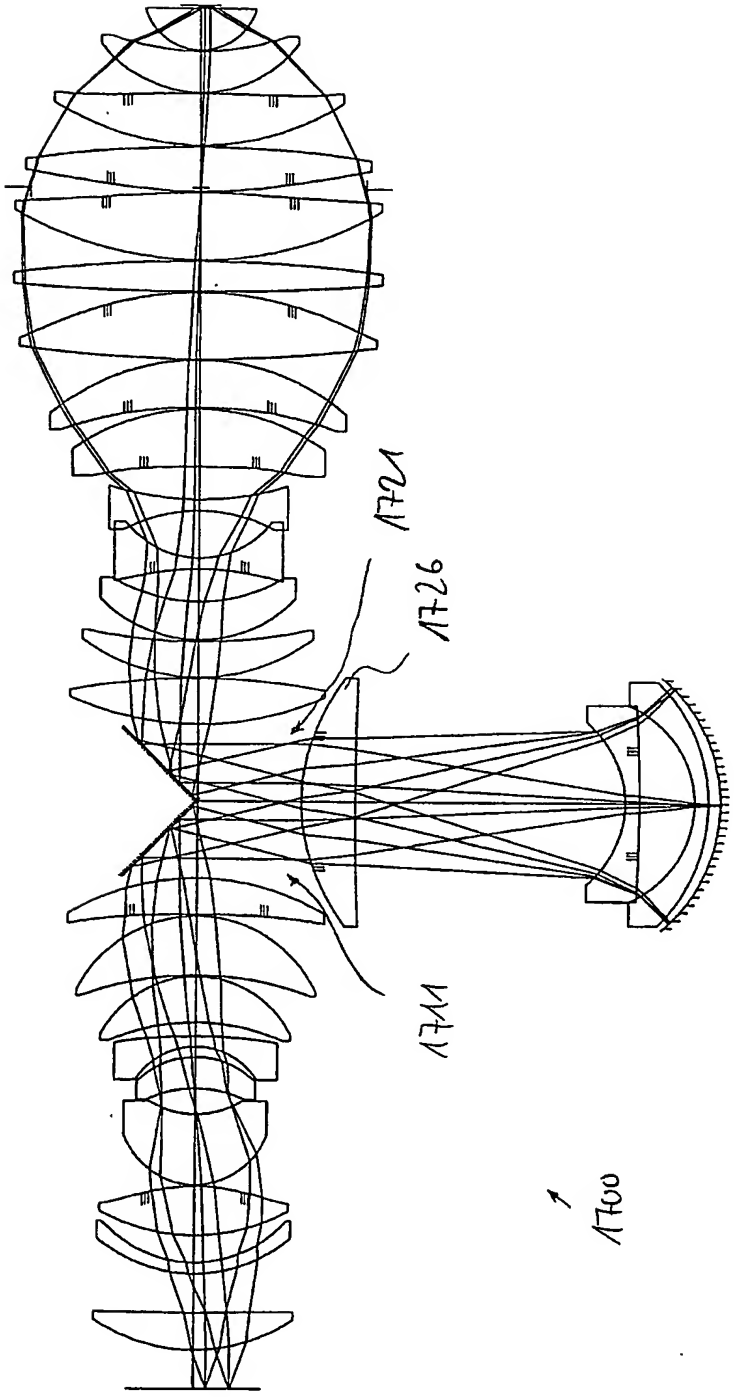

Fig. 17

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